On farm

Reducing sediment export from the Burdekin Catchment

Volume II Appendices

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Natural Resources

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Appendix 1. Distribution of alluvial gully systems along the Upper Burdekin River

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Background

Initial reconnaissance field work near 'Blue Range' in August 1999 alerted researchers to high levels of gully erosion along the Upper Burdekin River. Mapping of gully erosion in the Burdekin Catchment is limited to those areas investigated in Prosser et al (2001), and it was considered important to investigate further whether these erosion sites are a potential high source of sediment to the Burdekin River. Suggestions of how these erosion systems were formed and their role in contributing sediment to the Burdekin River are discussed below.

Approach

To assess the position and extent of gully erosion along the Burdekin River between the headwaters of the Burdekin River and Hillgrove we hired a plane and mapped erosion sites using a GPS. Photos of the sites were taken with a digital camera.

Results

Erosion sites within 500 m to 1000 m of the river banks were considered as potential sources of sediment. Any erosion sites further away from the river were not included. There were five different land types identified: bank erosion (e.g. Figure 1.1), gully bank erosion (e.g. Figure 1.2), erosion scalds (e.g. Figures 1.3), tributary sources of sediment (e.g. Figure 1.4) and wetlands (e.g. Figure 1.5). A map of the distribution of each of these erosion types is shown in Figure 1.6.

Figure 1.1: Bank erosion along the Upper Burdekin

Figure 1.2: Gully erosion scalds within 200 m of the Burdekin River

Figures 1.3: Erosion scalds along the banks of the Burdekin River

Figure 1.4: Tributary sources of sediment

Figure 1.5: Valley of the Lagoons is an important wetland habitat along the Upper Burdekin

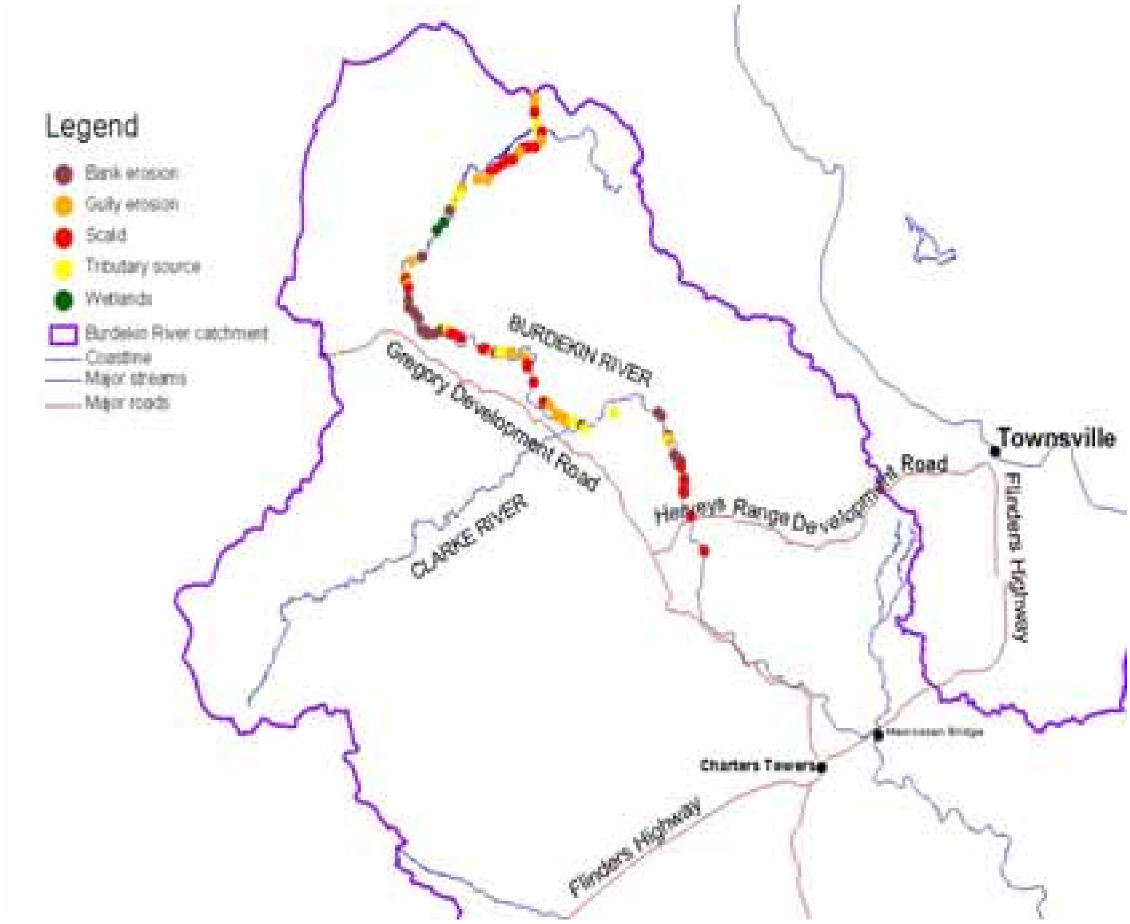

Figure 1.6: Map of location of gully systems along the Upper Burdekin

Estimating the impact of the erosion along the Upper Burdekin

It was initially proposed to estimate the contribution of these eroded sites to the overall sediment yield at Macrossan's Bridge. However, to do this, knowledge of erosion rates, dates of the erosion event, area of erosion surfaces and historical flow records would be required. Such a study would take considerable time and resources (even to make a rough calculation) and is therefore considered beyond the capacity of the project. Instead, a few qualitative suggestions as to the possible causes of this erosion and potential areas of further research are discussed.

The extent of erosion along the Upper Burdekin River is certainly more significant that originally mapped in Prosser et al., (2001). However, it is difficult to determine the causes of such extensive erosion. There are two probable causes:

1. excessive stocking rates on fragile soil and vegetation types; and
2. mining activities along the floodplains.

Based on the flight data, it seems that there are a number of large scalds located near and around stock watering points. Stock watering points are often located on the more vulnerable alluvial deposits of the floodplain or low-lying secondary channels (flood-runners), that when disturbed, can be stripped from the surface via floodwaters.

The bank erosion appears to be the result of a number of factors. In some cases the bank erosion looks to be directly related to high flood events that would cause scouring and slumping of the channel banks. In other cases it looks like miniature gullies ('badlands') have formed because of high surface runoff from hill-slopes running over the bank to the main channel. This process looks to be directly related to low vegetation cover in many areas. In some cases it does appear that bank erosion has been exacerbated by stock access to the main channel.

It is uncertain of the impact of mining along the floodplains and within the main channel. There is direct evidence of mine sites within a few kilometres of the main channel (Figure 1.7); however, it is difficult to determine to what level the rest of the landscape has been impacted by historical mining activities. It may be that some of the erosion is a function of sluicing activities related to tin mining.

Figure 1.7: Mine site located within a few kilometres of the Burdekin River

Suggested areas of further research

To fully understand the contribution of these erosion sites to the overall sediment yield from the Upper Burdekin River, a number of activities need to be carried out:

1. The erosion sites need to be mapped on aerial photos. Using stereo- photogrammetry estimates of soil volumes can be made. Such mapping would also need to be verified in the field.
2. Estimates of the date or time of erosion needs to be made so that a rate of soil loss can be determined. This may require the use of sophisticated techniques such as OSL (optical stimulated luminescence) dating or tracing techniques using ^{210}Pb or other radionucleide tracers. Without such information it is difficult to determine if these features are related to land-use (and which land-use has been the main cause).
3. An historical investigation into the extent of mining activities in the region would be an important exercise.
4. A general investigation into the flood history, stock management history and vegetation changes of the area would also assist in understanding when the erosion began in this area and which factors were the most important in triggering the erosion observed.
5. On the basis of the above, incorporate a new component with Sednet that models the contribution of these major riverine systems on sediment delivery and revise the Burdekin sediment budget.

Appendix 2. Using microplots to capture landscape runoff and suspended sediment characteristics

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Summary

Microplots are designed to help describe surface hydrology characteristics and sediment transport for varying soil types and landforms.They are a cost effective, low maintenance tool that provides good seasonal response data about infiltration and suspended sediment transport for different vegetation coverage. A number of units dispersed around the major component types of the landscape can provide data diagnostic of the area.

Introduction

Microplots were primarily designed to capture quantitative data relating to hill slope runoff and associated suspended sediment loss, so that the relationships between these characteristics and vegetation cover may be investigated. Three vegetation cover classes were implemented for this study. Bare of scald (<25%), low-med cover (25-75%) and high cover (>75%). Two repetitions of each cover type were implemented at two separate sites (12 in total).

Microplots comprise of two main parts (figure 2.1), the frame and the Sample Collection Unit (SCU). Table 2.1 provides a breakdown of the individual components of the microplots.

The frame sits ~25mm above the soil surface, isolating the area inside, so that the characteristics of a fixed area (0.24 m^2) can be determined and compared against other plots. Runoff from the plot collects in the trough at the base of the frame and then drains to the Sample Collection Unit.

A small bund wall provides protection from upslope runoff that may compromise the frame walls, or result in hillslop flow overtopping into the microplot.

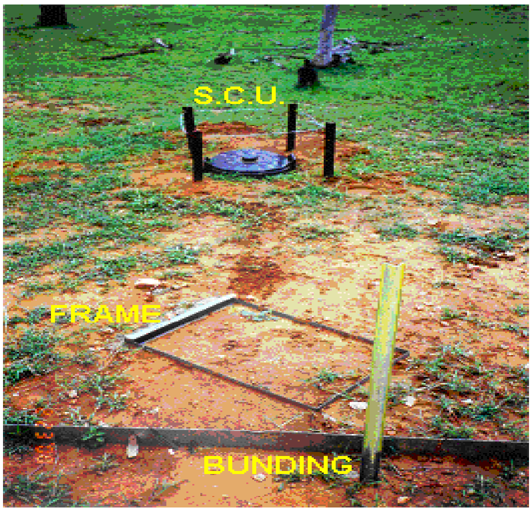


Figure 2.1: An installed microplot

Table 2.1: Microplot components & descriptions.

Component	Dimensions	Material / Description
Frame	600 x 400 x 50 (mm)	1.2mm zinc anneal
Trough	400 x 40 x 30 (mm)	1.2mm zinc anneal
Hose	16mm (diam) 2mm thick	Clear vinyl
Bin	44 L	Plastic garbage bin with lid
Drum	25 L	Plastic water storage
Fence		Star pickets (cut into 4 pieces) 1 strand of barbed wire
Rod	6 mm (diam)	Mild steel (cut into appropriate lengths)

Installation

Microplot frame

To insert the microplot frame into the soil, an angle grinder was used to cut around the outline of a solid template constructed out of sheet metal. The template also served to protect the area inside the microplot from disturbance. The microplot frame was then put into the resulting rectangular trench and a board, slightly larger in area than the frame, placed on top. Standing on the board, the frame was tapped into place with a hammer. Periodic rotation of strike points (eg clockwise from corner to middle to corner etc) above the frame edge ensured an even insertion. The frame was inserted so that the trough attachment would be flush with the ground surface.

At the downslope edge, a small hole was carefully excavated to allow for the emplacement of the trough. This excavation was made slightly deeper and wider to allow room for a mortar base (sand, cement & water). The trough was then inserted into the wet mortar, slotted into the frame and the cover emplaced. The frame walls were then repacked with soil of a similar type to form a tight seal between the frame and the soil surface. Figure 2.2 shows the microplot frame and trough after installation.

Figure 2.2: Microplot frame and trough

Sample collection unit

Downslope from the microplot a posthole auger was used to excavate a hole to the depth of the bin lip. A crowbar and a posthole shovel were needed to increase the diameter and to tidy up the excavation. With the bin in the excavation, the storage drum was placed inside and the bin marked at the top edge of the drum. This point should be slightly below ground level to allow for burial of the hose and flow of water from the microplot. After the drum and bin were removed from the excavation, a 20mm hole was drilled, at the marked point, to facilitate insertion of the hose to the drum.

When the mortar around the trough had set, a shallow trench of about 5cm was dug from the microplot to the SCU. The vinyl hose was attached to the trough and run along the trench and inserted into the drum through the hole in the bin wall. A small volume of water was run into the trough to ensure flow to the drum. When flow was achieved the drum was removed and the bin secured with 4 ‘L’ shaped steel rods through the sidewalls. 4 holes were punctured in the base of the bin to allow for faster drainage. With the hose free of kinks or creases the trench was backfilled to keep the hose free from bovine interference. After the drum was reinserted another rod was pierced through, the bin wall, passed under the handle of the drum and then pierced out the other side of the bin to hold the drum firmly in place.

The lid was placed on the bin and then excavated soil used to fill any voids between the outside bin wall and the soil. The rest of the excavated soil was used for constructing a raised bund wall on the upslope side of the SCU to deflect overland flow. A drainage trench was made on the downslope side of the bin unit to a depth just below the bin lip.

A small barbed wire fence was needed to protect the unit from trampling by cattle. This was constructed by cutting star pickets into approximately 500mm lengths. 4 lengths were driven into the ground around the SCU to form a square. Barbed wire was securely attached to the top of one star picket. A small groove about 10mm long and 5mm wide was cut into the outermost top edge of each of the other pickets. The barbed wire was loosely wrapped around the pickets, seated in the grooves, and then securely attached to the first picket. The wire was wrapped loosely enough to allow removal for easy access to the unit but not loose enough to come free when disturbed. Figure 2.3 shows an installed SCU.

Figure 2.3: The sample collection unit

Bund wall

A sheet metal bund wall was placed slightly upslope from the microplot frame to abate flooding of the microplots from upslope overland flow. (See Figure 2.1.) This metal strip was approximately 150mm high by 600mm long and was simply tapped into the soil with a hammer.

Measurements

Volume

A compilation of the data obtained from the microplots is provided in Table 2.2. To measure the volume of overland flow from the microplot, the barbed wire fence from around the sample unit was removed. The lid of the bin was removed, as was the hose from the drum. The drum was then shaken to disperse any settled sediments. The volume was determined using a measuring cylinder and a 250ml sub-sample was transferred to a labelled bottle (Plot Name, Date and Total Volume). The total volume, vegetation cover and any other relevant comments were recorded to the lab book and later added to an Excel Spreadsheet (see Table 2.2). Sub-samples were refrigerated on return to the laboratory. These were later analysed for total suspended sediments and turbidity.

Vegetation Cover

The amount of vegetation cover obstructing raindrop impact was estimated for each plot at every sample collection date. Estimates were in the form of percentage cover. Any litter that was thick enough to protect the soil from raindrop compaction was included. Results of the cover estimates are presented in Figure 2.4 and Table 2.2.

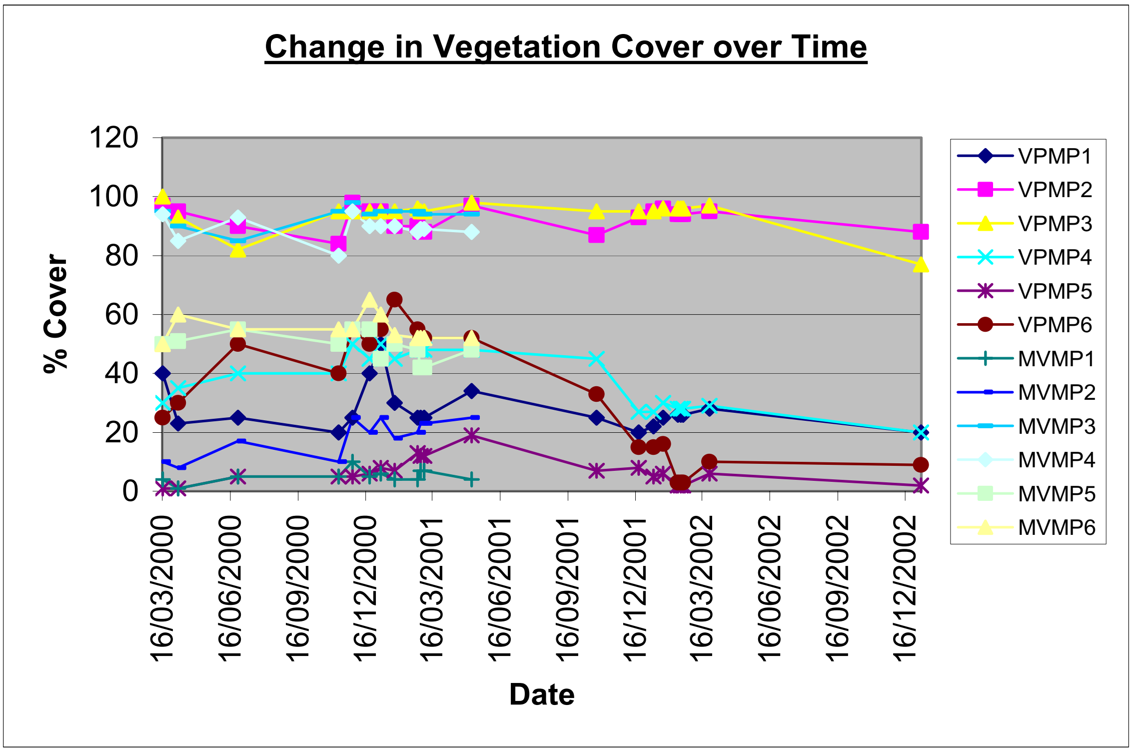


Figure 2.4: Overview of ground cover estimates for all microplots during the project life

Slope

The slope gradient for each microplot was taken by measuring the fall in ground level from the top of the plot, to the lip of the trough. A spirit level and tape measure was used.

Problems encountered

Cattle impacts

Residing cattle occasionally trampled the microplots. Damage from such events included, warped or flattened edges and skewing of the whole frame, to the total dislodgment of the trough. When frame warping had occurred, the frame was reshaped (in-situ if possible) and any gaps between the walls and the soil refilled and packed as per installation procedure. Trough dislodgment posed a more difficult problem. The troughs were cemented in and tend to dislodge with the cement base attached. To remedy the problem some further excavation was required, the trough reinserted and packed into place with stones and soil. A small amount of water was then run down the trough to ensure proper drainage.

Figure 2.5: Trampling caused by cattle

Figure 2.6: Coarse sediment trapped in trough

Blockages

It was discovered that periodically, the troughs would trap larger sediment particles (primarily sand) that would collect at the drainage hole, causing dysfunction. It is believed that these soil particles are moved by raindrop impact and that when they enter the trough, the runoff does not have enough energy to move the particles. This build up was easy to remove with the aid of a screwdriver (to break up cemented particles) and a small paintbrush (used in with dusting action), then washed out with water to ensure through flow. Some blockages extended a small way down the hose. Initially, when this occurred, the rod holding the drum in place was used to dislodge the blockage and then water was flushed down the line until it ran clear. A better method of unblocking the hose was then utilised. With one end blocked, the hose was then filled with water. Compressed air was applied to the hose ejecting the blockage with the water.

The drainage hole in the troughs and the troughs themselves provide excellent accommodation for spiders of the family *Lycosidae*. Redback spiders (*Lactrodectus hasselti)* were sometimes found with webs in the trough so care was taken when removing the trough cover. The webs built by both of these types of spiders created a barrier to throughflow, ultimately causing sediment build up and unit dysfunction. The spiders were removed with small twigs or screwdrivers and then the trough and drainage line cleaned out with water.

On one occasion, it was discovered that a cow had walked on the wet soil covering the drainage hose. The soil compacted considerably forcing the hose closed, effectively blocking flow. Barriers were then placed directly above the hose to mitigate future repeat occurrences.

Sealing

For the microplots to function correctly, the contact between the frame and the soil must be maintained. Natural erosion/deposition events and cattle interactions occasionally compromised the integrity of the contact. The contact was re-established by filling the gaps with a similar soil and which was then carefully packed to ground level. Moistening of the filled areas then allowed a tighter seal to be established. From time to time, erosion (primarily micro-rilling) compromised the contact between the trough lip and the ground.

Rainfall intensity effects

Rainfall events with an intensity >20mm/hr decreased the probability of the equipment capturing quantitative runoff samples. The results from these events were either high 25 litre counts or certain plots would have suspiciously low volumes due to early blockage (especially low cover plots). It was assumed that the 25 litre volumes resulted as a consequence of the plot-frame walls being compromised by excessive overland flow. Figure 2.7 compares the resulting outputs from moderately high and low intensity events for the microplots at Virginia Park & Meadowvale Stations near Mingela, Queensland, Australia. The TSS results also followed a similar trend as shown in Figure 2.8.

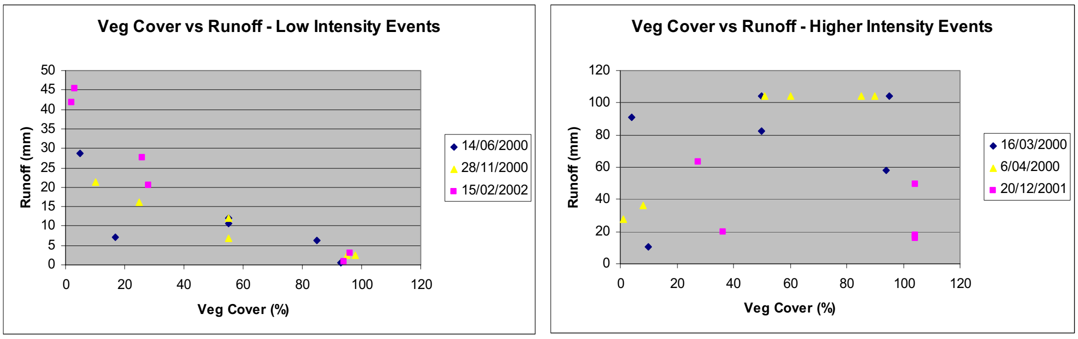


Figure 2.7: Rainfall intensity effects on veg Cover / runoff Volume relationships.

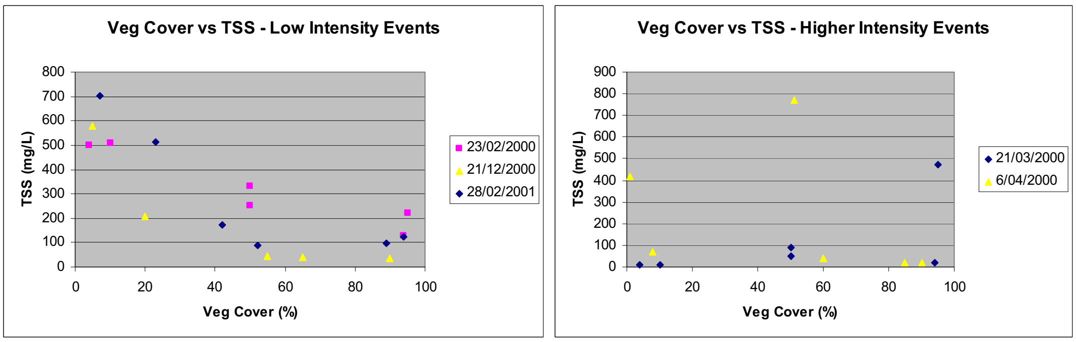


Figure 2.8: Rainfall intensity effects on TSS / Veg cover relationships.

Improvements

Frame

The thickness of the metal used for the frame could be increased. This would improve its ability to withstand trampling by cattle. It would also allow for the depth of the frame to be increased without impeding a clean install. An increase in frame depth may help to abate some problems associated with high intensity events.

Trough

A removable trough would greatly improve the access for cleaning and perhaps with frame realignment. It may also prove beneficial to locate the drainage hole centrally, rather than on the side, so that the drainage hose can be kept straight. This would improve the units' ability to 'self clean', minimising blockages by heavier soil particles.

Site selection/ alignment

Care should be taken to align the troughs directly downslope so that water and sediment does not have the potential to build up along the frame walls (i.e. the frame does not impede the flow of the water downslope). Microplots situated in depressions require extra bunding, which even then, may not provide adequate protection from overland flow (depending on the soil characteristics). For example, microplot MVMP3 was installed in a shallow drainage line and always seemed to be full or much fuller than it should be (especially on med-high intensity events). It was then discovered that increased overland flow was able to 'wrap around' the bunding and overtop the frame walls.

Table 2.2: Compilation of data obtained from the microplots

Date Collected	Sample	Cover (%)	Total Rainfall (mm)	MaxRain Intensity (mm/hr)	Runoff Volume (mm)	Runoff (%)	TSS (mg/L)	Turbidity (NTU)	TDS (mg/L)
23-Feb-00	VPMP3	100	118.2	42.80	63.63	53.83	0.00	47	24
23-Feb-00	VPMP4	30	118.2	42.80	75.95	64.26	773.20	2830	12
23-Feb-00	VPMP5	1	118.2	42.80	61.10	51.70	955.31	3475	12
29-Feb-00	MVMP2	10	70	5.70	12.92	18.45			
29-Feb-00	MVMP4	94	70	5.70	21.33	30.47			
01-Mar-00	VPMP1	40	48	12.10	5.63	11.72	110.00		30
01-Mar-00	VPMP6	25	48	12.10	38.75	80.73	432.00		18
21-Mar-00	MVMP1	4	145	19.40	91.25	62.93	226.00	865	6
21-Mar-00	MVMP2	10	145	19.40	10.63	7.33	0.00		12
21-Mar-00	MVMP5	50	145	19.40	82.71	57.04	0.00	478	12
21-Mar-00	VPMP2	97	110	22.70	4.77	4.34	2.00		48
21-Mar-00	VPMP3	100	110	22.70	8.19	7.44	0.00		18
21-Mar-00	VPMP4	30	110	22.70	42.50	38.64	18.00		12
21-Mar-00	VPMP6	25	110	22.70	91.04	82.77	348.00		12
06-Apr-00	MVMP4	85	230.7	36.40	104.17	52.08	8.00		12
06-Apr-00	MVMP5	51	230.7	36.40	104.17	52.08	16.00	1258	12
06-Apr-00	MVMP6	60	230.7	36.40	104.17	52.08	28.00		12
06-Apr-00	VPMP1	23	130	27.60	74.54	57.34	518.00		12
06-Apr-00	VPMP3	93	130	27.60	104.17		42.00		18
06-Apr-00	VPMP4	35	130	27.60	104.17		298.00		12
14-Jun-00	MVMP1	5	46.5	3.52	28.65	61.60			
14-Jun-00	MVMP2	17	46.5	3.52	7.17	15.41			
14-Jun-00	MVMP3	85	46.5	3.52	6.29	13.53			
14-Jun-00	MVMP4	93	46.5	3.52	0.46	0.99			
14-Jun-00	MVMP5	55	46.5	3.52	12.04	25.90			
14-Jun-00	MVMP6	55	46.5	3.52	10.58	22.76			
26-Jun-00	VPMP1	25	97	3.80	1.04	1.07			
26-Jun-00	VPMP2	90	97	3.80	0.50	0.52			
26-Jun-00	VPMP3	82	97	3.80	0.63	0.64			
26-Jun-00	VPMP4	40	97	3.80	0.71	0.73			
26-Jun-00	VPMP5	5	97	3.80	7.50	7.73			
26-Jun-00	VPMP6	50	97	3.80	0.92	0.95			
09-Nov-00	MVMP1	5	99	35.52	60.00	60.61			
09-Nov-00	MVMP4	80	99	35.52	16.46	16.62			
09-Nov-00	MVMP5	50	99	35.52	10.52	10.63			
09-Nov-00	VPMP 1	20	115.5	27.80	34.58	29.94	595.40	615	24.6
09-Nov-00	VPMP 2	85	115.5	27.80	9.58	8.30	135.80	56	124.2
09-Nov-00	VPMP 3	95	115.5	27.80	10.00	8.66	35.60	9	44.4
09-Nov-00	VPMP 4	40	115.5	27.80	26.56	23.00	520.80	526	19.2
09-Nov-00	VPMP 6	40	115.5	27.80	25.52	22.10	847.80	1070	22.2
17-Nov-00	MVMP1	5	30.5	18.69	21.46	70.36			
17-Nov-00	MVMP2	10	30.5	18.69	16.67	54.64			
17-Nov-00	MVMP4	80	30.5	18.69	19.27	63.18			
17-Nov-00	MVMP5	50	30.5	18.69	8.02	26.30			
17-Nov-00	MVMP6	55	30.5	18.69	5.63	18.44			

Date Collected	Sample	Cover (%)	Total Rainfall (mm)	MaxRain Intensity (mm/hr)	Runoff Volume (mm)	Runoff (%)	TSS (mg/L)	Turbidity (NTU)	TDS (mg/L)
17-Nov-00	VPMP 1	20	19.5	1.50	3.17	16.24	295.40	298	24.6
17-Nov-00	VPMP 4	40	19.5	1.50	3.29	16.88	199.00	197	21
17-Nov-00	VPMP 5	5	19.5	1.50	7.40	37.93	258.00	294	12
17-Nov-00	VPMP 6	40	19.5	1.50	2.06	10.58	258.40	288	21.6
28-Nov-00	MVMP1	10	43.5	6.66	21.25	48.85			
28-Nov-00	MVMP2	25	43.5	6.66	16.04	36.88			
28-Nov-00	MVMP3	98	43.5	6.66	2.46	5.65			
28-Nov-00	MVMP4	95	43.5	6.66	2.40	5.51			
28-Nov-00	MVMP5	55	43.5	6.66	6.75	15.52			
28-Nov-00	MVMP6	55	43.5	6.66	11.92	27.39			
28-Nov-00	VPMP 1	25	50	20.50	22.17	44.33	576.20	599	13.8
28-Nov-00	VPMP 2	98	50	20.50	6.25	12.50	100.60	13	59.4
28-Nov-00	VPMP 3	95	50	20.50	23.13	46.25	56.00	23	24
28-Nov-00	VPMP 4	50	50	20.50	14.48	28.96	645.00	695	15
28-Nov-00	VPMP 5	5	50	20.50	8.96	17.92	336.80	416	13.2
28-Nov-00	VPMP 6	55	50	20.50	13.33	26.67	594.40	751	15.6
21-Dec-00	MVMP1	5	92.4	9.90	52.08	56.37			
21-Dec-00	MVMP2	20	92.4	9.90	35.10	37.99			
21-Dec-00	MVMP4	90	92.4	9.90	20.73	22.43			
21-Dec-00	MVMP5	55	92.4	9.90	21.46	23.22			
21-Dec-00	MVMP6	65	92.4	9.90	26.88	29.09			
21-Dec-00	VPMP 1	40	129	19.80	60.63	47.00	270.10	280	9.9
21-Dec-00	VPMP 2	95	129	19.80	9.27	7.19	64.00	7.5	36
21-Dec-00	VPMP 4	45	129	19.80	22.08	17.12	113.20	102	16.8
21-Dec-00	VPMP 5	6	129	19.80	57.92	44.90	602.50	740	7.5
21-Dec-00	VPMP 6	50	129	19.80	58.23	45.14	192.20	225	7.8
05-Jan-01	MVMP1	6	72.5	26.83	53.96	74.43			
05-Jan-01	MVMP2	25	72.5	26.83	60.71	83.74			
05-Jan-01	MVMP4	90	72.5	26.83	49.79	68.68			
05-Jan-01	MVMP5	45	72.5	26.83	28.75	39.66			
05-Jan-01	MVMP6	60	72.5	26.83	45.63	62.93			
05-Jan-01	VPMP 1	50	66.4	33.70	22.50	33.89	671.00	614	9
05-Jan-01	VPMP 2	95	66.4	33.70	4.79	7.22	99.40	23	30.6
05-Jan-01	VPMP 3	95	66.4	33.70	40.00	60.24	65.60	15	14.4
05-Jan-01	VPMP 4	50	66.4	33.70	12.79	19.26	189.20	156	10.8
05-Jan-01	VPMP 5	8	66.4	33.70	67.50	101.66	919.80	920	10.2
05-Jan-01	VPMP 6	55	66.4	33.70	25.00	37.65	540.40	624	9.6
24-Jan-01	MVMP1	4	21.5	8.88	11.88	55.23			
24-Jan-01	MVMP2	18	21.5	8.88	6.88	31.98			
24-Jan-01	MVMP3	95	21.5	8.88	0.00	0.00			
24-Jan-01	MVMP4	90	21.5	8.88	0.10	0.48			
24-Jan-01	MVMP5	50	21.5	8.88	0.21	0.97			
24-Jan-01	MVMP6	53	21.5	8.88	5.21	24.22			
24-Jan-01	VPMP 1	30	30.6	15.70	4.27	13.96	211.10	163	18.9
24-Jan-01	VPMP 4	45	30.6	15.70	1.67	5.45	80.70	27.3	39.3
24-Jan-01	VPMP 5	7	30.6	15.70	7.50	24.51	1642.60	1795	17.4

Date Collected	Sample	Cover (%)	Total Rainfall (mm)	MaxRain Intensity (mm/hr)	Runoff Volume (mm)	Runoff (%)	TSS (mg/L)	Turbidity (NTU)	TDS (mg/L)
24-Jan-01	VPMP 6	65	30.6	15.70	1.67	5.45	128.80	117	31.2
22-Feb-01	MVMP1	4	44.25	12.58	7.92	17.89			
22-Feb-01	MVMP2	20	44.25	12.58	7.08	16.01			
22-Feb-01	MVMP3	95	44.25	12.58	0.10	0.24			
22-Feb-01	MVMP4	88	44.25	12.58	2.08	4.71			
22-Feb-01	MVMP5	48	44.25	12.58	2.71	6.12			
22-Feb-01	MVMP6	52	44.25	12.58	7.29	16.48			
22-Feb-01	VPMP 1	25	28.8	4.00	2.29	7.96	76.40	35	3.6
22-Feb-01	VPMP 2	90	28.8	4.00	1.25	4.34	92.00	16	78
22-Feb-01	VPMP 3	96	28.8	4.00	2.19	7.60	67.80	17	52.2
22-Feb-01	VPMP 4	48	28.8	4.00	2.29	7.96	64.60	43	35.4
22-Feb-01	VPMP 6	55	28.8	4.00	1.98	6.87	215.20	185	4.8
28-Feb-01	MVMP2	23	70.75	14.62	46.88	66.25			
28-Feb-01	MVMP3	94	70.75	14.62	44.79	63.31			
28-Feb-01	MVMP4	89	70.75	14.62	13.96	19.73			
28-Feb-01	MVMP5	42	70.75	14.62	22.92	32.39			
28-Feb-01	MVMP6	52	70.75	14.62	31.04	43.88			
28-Feb-01	VPMP 2	88	55.4	9.00	1.04	1.88	147.60	9	32.4
28-Feb-01	VPMP 3	95	55.4	9.00	2.71	4.89	55.40	4	24.6
28-Feb-01	VPMP 4	48	55.4	9.00	10.83	19.55	149.60	112	20.4
28-Feb-01	VPMP 5	12	55.4	9.00	22.71	40.99	729.20	840	10.8
28-Feb-01	VPMP 6	52	55.4	9.00	8.33	15.04	317.40	342	12.6
05-Mar-01	MVMP1	7	72.5	24.98	52.92	72.99			
05-Mar-01	MVMP2	23	72.5	24.98	62.71	86.49			
05-Mar-01	MVMP4	89	72.5	24.98	43.96	60.63			
05-Mar-01	MVMP5	42	72.5	24.98	45.63	62.93			
05-Mar-01	MVMP6	52	72.5	24.98	60.42	83.33			
05-Mar-01	VPMP 1	25	36.5	3.50	15.83	43.38	488.00	465	12
05-Mar-01	VPMP 2	88	36.5	3.50	1.88	5.14	54.00	8	36
05-Mar-01	VPMP 3	95	36.5	3.50	3.54	9.70	47.20	9	22.8
05-Mar-01	VPMP 4	48	36.5	3.50	16.04	43.95	183.20	163	16.8
05-Mar-01	VPMP 5	12	36.5	3.50	22.29	61.07	960.40	1140	9.6
30-Apr-01	MVMP1	4	52		38.96	74.92			
30-Apr-01	MVMP2	25	52		10.63	20.43			
30-Apr-01	MVMP4	88	52		18.33	35.26			
30-Apr-01	MVMP5	48	52		17.71	34.05			
30-Apr-01	MVMP6	52	52		10.42	20.03			
08-May-01	VPMP1	34	33.5	6.40	0.94	2.80			
08-May-01	VPMP2	97	33.5	6.40	0.63	1.87			
08-May-01	VPMP3	98	33.5	6.40	0.42	1.24			
08-May-01	VPMP4	48	33.5	6.40	0.52	1.55			
08-May-01	VPMP5	19	33.5	6.40	2.71	8.08			
08-May-01	VPMP6	52	33.5	6.40	0.52	1.55			
04-Dec-01	VPMP1	25	45	36.22	6.25	13.89			
04-Dec-01	VPMP2	98	45	36.22	1.67	3.70			
04-Dec-01	VPMP3	95	45	36.22	4.58	10.19			

Date Collected	Sample	Cover (%)	Total Rainfall (mm)	MaxRain Intensity (mm/hr)	Runoff Volume (mm)	Runoff (%)	TSS (mg/L)	Turbidity (NTU)	TDS (mg/L)
04-Dec-01	VPMP4	50	45	36.22	11.25	25.00			
04-Dec-01	VPMP5	5	45	36.22	20.42	45.37			
04-Dec-01	VPMP6	40	45	36.22	17.71	39.35			
20-Dec-01	VPMP1	20	237.25	54.90	63.33	26.69			
20-Dec-01	VPMP2	93	237.25	54.90	19.79	8.34			
20-Dec-01	VPMP3	95	237.25	54.90	49.17	20.72			
09-Jan-02	VPMP1	22	45	12.17	20.21	44.91			
09-Jan-02	VPMP2	95	45	12.17	4.17	9.26			
09-Jan-02	VPMP3	95	45	12.17	5.00	11.11			
09-Jan-02	VPMP4	27	45	12.17	25.63	56.94			
09-Jan-02	VPMP5	5	45	12.17	28.33	62.96			
09-Jan-02	VPMP6	15	45	12.17	27.50	61.11			
22-Jan-02	VPMP1	25	89.5	3.96	6.35	7.10			
22-Jan-02	VPMP2	96	89.5	3.96	1.88	2.09			
22-Jan-02	VPMP3	96	89.5	3.96	1.88	2.09			
22-Jan-02	VPMP4	30	89.5	3.96	3.54	3.96			
22-Jan-02	VPMP5	6	89.5	3.96	14.05	15.70			
22-Jan-02	VPMP6	16	89.5	3.96	12.50	13.97			
11-Feb-02	VPMP1	26	46.5	13.58	15.63	33.60			
11-Feb-02	VPMP2	94	46.5	13.58	2.29	4.93			
11-Feb-02	VPMP3	96	46.5	13.58	5.94	12.77			
11-Feb-02	VPMP4	28	46.5	13.58	19.38	41.67			
11-Feb-02	VPMP5	2	46.5	13.58	24.58	52.87			
11-Feb-02	VPMP6	3	46.5	13.58	29.17	62.72			
15-Feb-02	VPMP1	26	95	7.36	27.50	28.95			
15-Feb-02	VPMP2	94	95	7.36	0.83	0.88			
15-Feb-02	VPMP3	96	95	7.36	2.92	3.07			
15-Feb-02	VPMP4	28	95	7.36	20.63	21.71			
15-Feb-02	VPMP5	2	95	7.36	41.67	43.86			
15-Feb-02	VPMP6	3	95	7.36	45.42	47.81			
18-Feb-02	VPMP2	94	25.5	1.13	6.67	26.14			
18-Feb-02	VPMP3	96	25.5	1.13	20.00	78.43			
18-Feb-02	VPMP4	28	25.5	1.13	19.17	75.16			
18-Feb-02	VPMP5	2	25.5	1.13	12.71	49.84			
26-Mar-02	VPMP2	95	35	11.04	1.04	2.98			
26-Mar-02	VPMP3	97	35	11.04	2.50	7.14			
26-Mar-02	VPMP4	29	35	11.04	8.75	25.00			
26-Mar-02	VPMP5	6	35	11.04	19.17	54.76			
26-Mar-02	VPMP6	10	35	11.04	17.08	48.81			
06-Jan-03	VPMP1	20	20.94	20.94	18.54	88.55			

Appendix 3. Methods for monitoring ephemeral streams

David Fanning, Peter Fitch and David Post, CSIRO Land and Water, Townsville

Introduction

As part of the project it was necessary to construct and install stream guaging stations at three sites in the Mingela region. The purpose of these stations is to provide high temporal resolution data on the stream hydrograph and turbidity levels. Each site is equipped with an automated sampler to correlate suspended sediment with the turbidity measurements. The sites are at Weany, Wheel and Station Creeks. Turbidity measurements were also taken in the Burdekin River to be used in conjunction with existing discharge monitoring by NR&M.

This document has been prepared to describe a mechanical bottle sampler developed and deployed at Weany and Wheel Creeks. The construction of the gauging stations is also detailed and the instrumentation deployed is outlined.

Weany and Wheel Creeks

Mechanical bottle sampler

An automatic, mechanical in stream water sampling device was designed in response to a request for a robust, low cost, reliable method of sampling suspended sediment in ephemeral streams in the Burdekin catchment, North Queensland.

The instream bottle sampler is series of discrete modules each containing a single bottle (250 mL), a closing mechanism and a clamping system (Figures 3.1 and 3.2). It is constructed of a series of simple to manufacture components and "off the shelf" parts, as shown in Figures 3.3 to 3.6.

In operation the sampler is set at bottle open in a dry stream, when the stream rises the bottle fills then a float triggers a lever to seal the bottle bringing magnets together to hold the seal in place.

Figure 3.1: Single bottle sampler

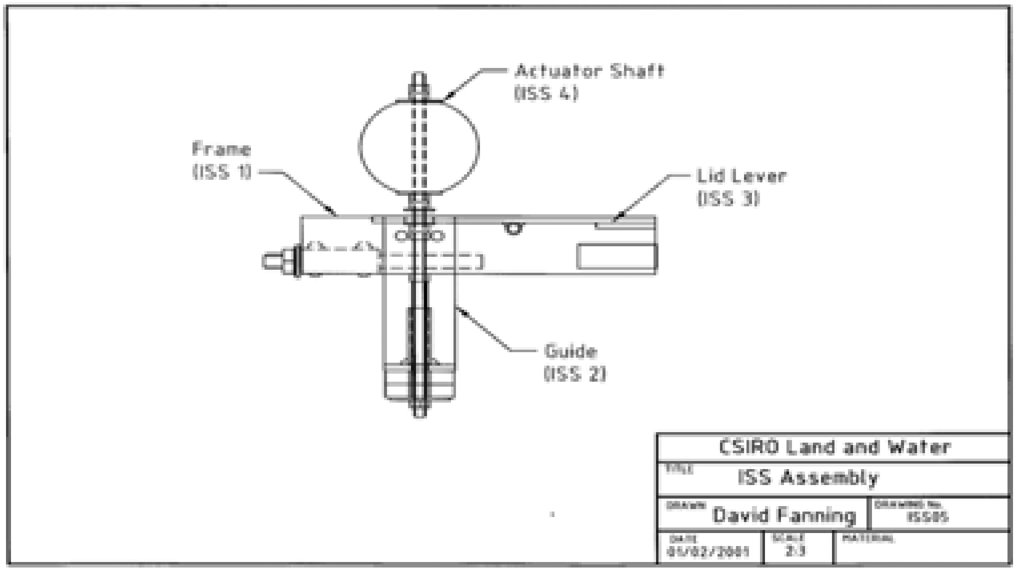


Figure 3.2: Assembly drawing of bottle sampler

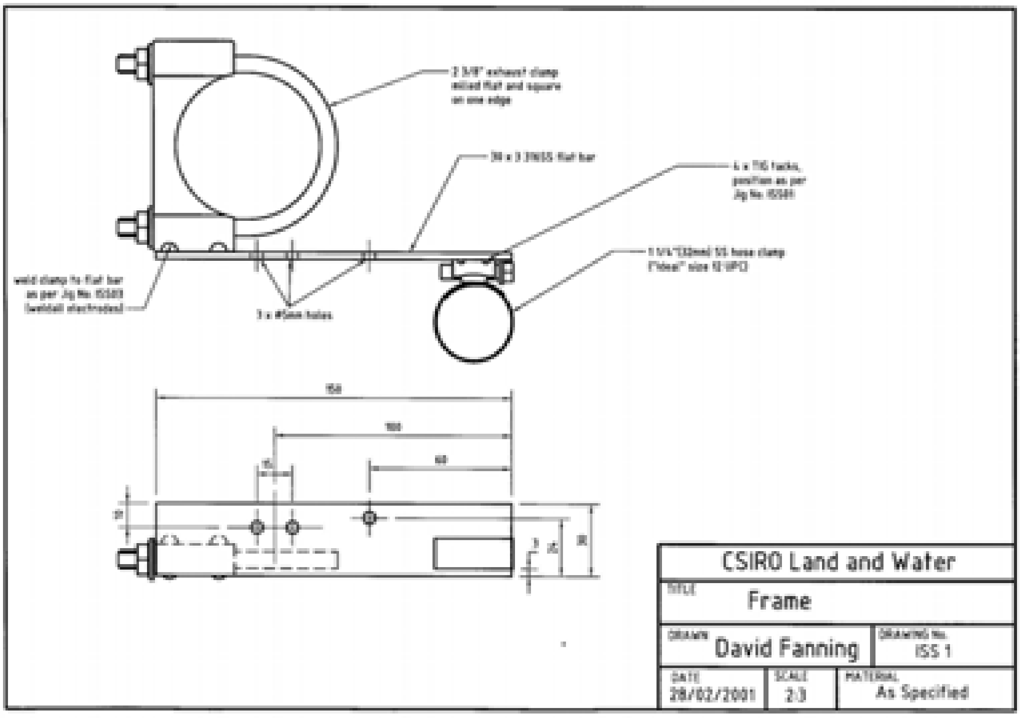


Figure 3.3: Drawing of frame component of bottle sampler (0.5 x scale)

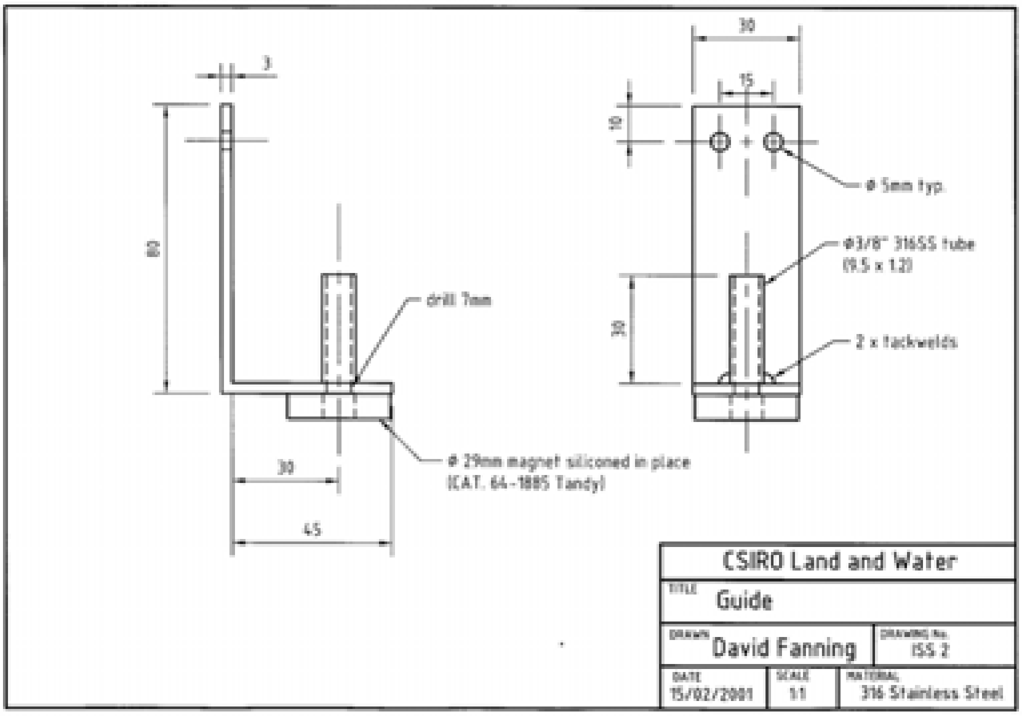


Figure 3.4: Drawing of guide component of bottle sampler (0.5 x scale)

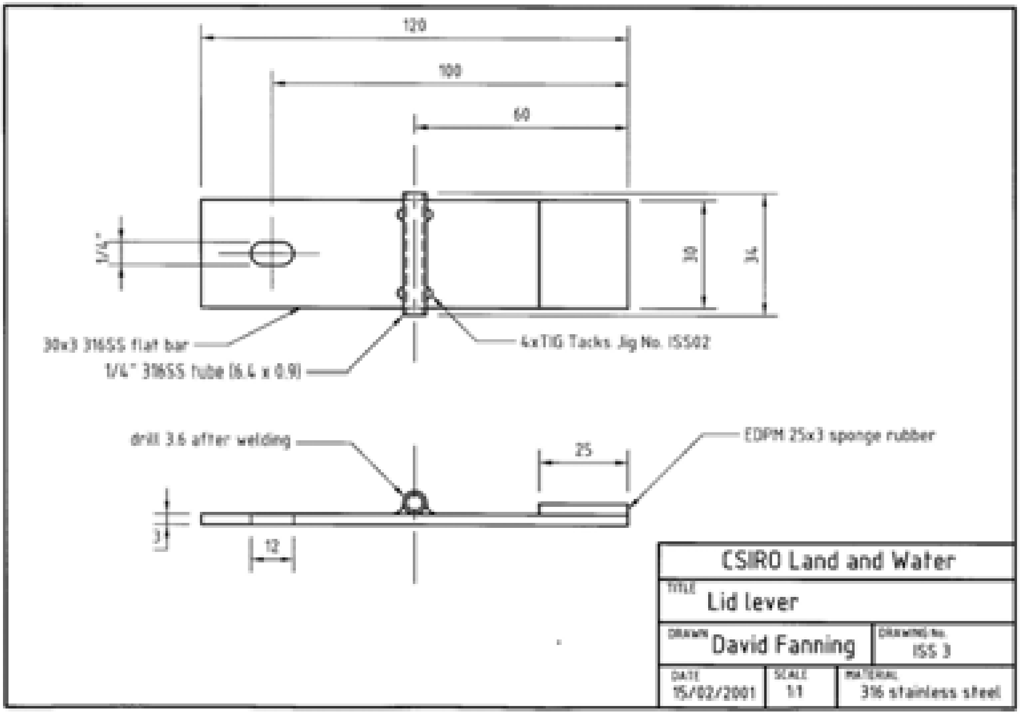


Figure 3.5: Drawing of lid lever component of bottle sampler (0.5 x scale)

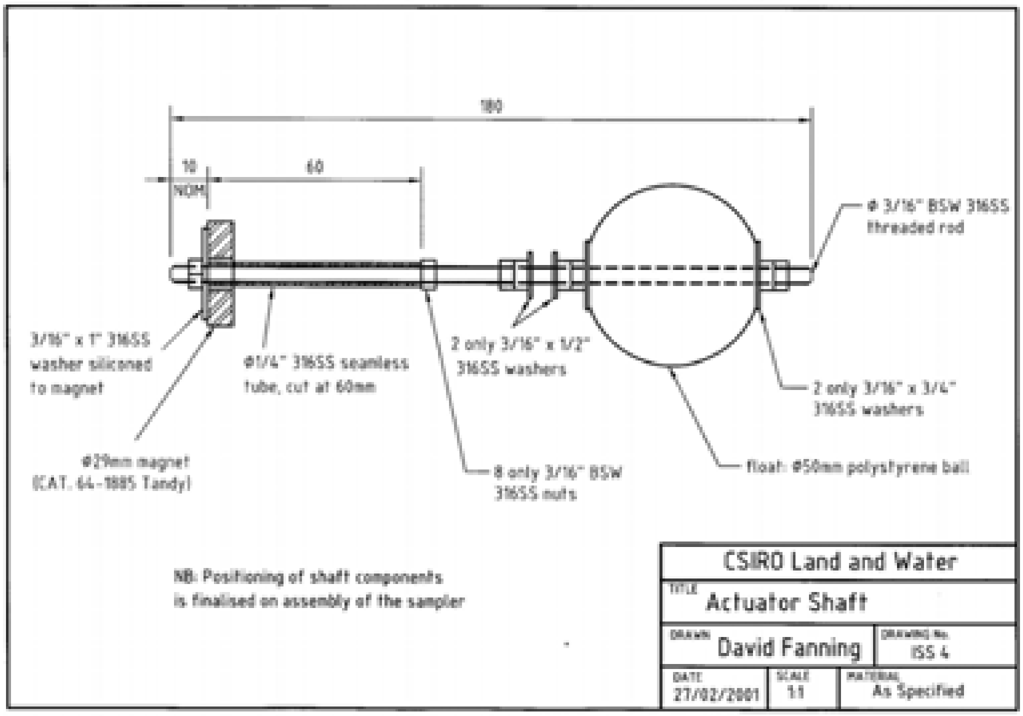


Figure 3.6: Drawing of actuator shaft component of bottle sampler (0.5 x scale)

Infrastructure and installation

The samplers are contained in a protective enclosure (Figure 3.7) consisting of a frame of two poles of 65 x 65 x 4 mm RHS and one central pole of 2” diameter medium wall water pipe. The shrouds are 460 mm diameter trench drain, which is supplied standard in half sections 1500 mm long with flanged sides, corrugated surface and slotted.

Figure 3.7: Arrangement of bottle samplers in enclosure at Weany Creek.

The two square outer poles and the round central pole were aligned and welded in place at top and bottom of 4 m sections with 65 x 6 mm flat bar on site (Figure 3.8). In order to key the frame into the concrete, eight sections of 25 x 25 mm RHS approximately 500 mm long were welded to the base of the outer poles from 0 to 1 m at right angles (Figure 3.9).

A small backhoe was maneuvered into the dry streams and a hole in each approximately 1.5 m deep x 1 m wide x 1.5 m long was excavated. The frame was jostled into position and concreted to a level about 0.5 m below surface using a sand (with limited gravel) mix from downstream. The top 0.5 m of the hole was refilled with the original sand and the site cleaned to represent the original streambed form.

Figure 3.8: Welding poles in place and cleaning out hole in preparation for concreting.

On the upstream side of the enclosure the shrouds were screwed into position then stainless steel through bolts were used to fix the downstream side, making the downstream side removable for sample recovery and servicing. To exclude precipitation an A-frame of 25 x 3 mm mild steel was welded to the top of the main frame and a low angle cone, manufactured in light gauge (0.55 mm) galvanized sheet steel, was screwed to this A-frame.

Figure 3.9: Frame with “keys” ready to be concreted into place.

Electronic Instruments

Water depth

A pressure transducer with a 392 single channel logger, supplied by Dataflow, Australia, was used initially with the bottle samplers to record water depth changes during stream-flow events.

The transducer was attached to the square section steel with conduit clips at streambed level and the logger was clipped inside the top of the enclosure for protection.

Turbidity

As a later addition a turbidity meter was added to both Weany and Wheel Creeks. The sensors used (supplied by Greenspan Technology, Australia) have a built in data logger to constantly record turbidity readings during stream-flow events.

The turbidity meters were housed in 316 stainless steel pipes oriented downstream for protection and attached to the outside of the enclosure at a height of 300 mm above the streambed. The cables were fed in and stored inside the top of the enclosure.

Velocity

The next addition was a Starflow ultrasonic Doppler velocity meter with a micrologger, supplied by Unidata, Australia.

The velocity meter was installed by knocking in a 1.5 m length of 2" galvanized, medium wall pipe with a sledgehammer, at a distance of 1.5m in front of the enclosure to minimise any flow disruption. The pipe had a section of 50 x 6 mm flat bar welded to the front top to enable bolting a support plate to mount the velocity meter at a height of 300m above the streambed (Figure 3.11). The cable was buried with the cable ends stored in the top of the enclosure for access for downloading.

Automatic Water Sampler

After the first year of sampling, an automated water sampler (ISCO 3700 series sampler, supplied by John Morris Scientific) was added to the system along with a Campbell CR10X logger (Campbell Scientific, Australia). The sampler has a capacity of 24 1L sample bottles.

Logging Regime

All instruments were connected to the Campbell logger, simplifying operation of the station and allowing greater control of the water sampler activation according to depth changes recorded. The logger is setup to scan for level changes every 60 seconds and log parameters every hour. When the water level increases over 30cm, the system goes into "event mode" and logs parameters every minute. The sampler is configured to take a sample each 100 mm rise and each 200 mm fall in the hydrograph.

The new system has also facilitated the direct transfer of the data back to Davies Laboratory via mobile phone. Since the ISCO water sampler and the Campbell logger must be kept dry they have been placed on platforms.

Platforms

Platforms were constructed on site to raise the new equipment above flood level and support a solar power supply and telemetry. At Weany Creek the platform is about 1.2 m high (Figure 3.10) and at Wheel Creek it is 2 m high (Figure 3.11). The wiring is suspended on steel cable and protected in corrugated conduit.

Figure 3.10: Platform at Weany Creek. Box containing auto sampler is on left; datalogger, control unit and solar panel on right hand corner of platform. Sampling device is seen in the background.

Figure 3.11: Gauging station at Wheel Creek. Sampling device with attached turbidity sensor and stand alone flow velocity meter in foreground; platform with autosampler in background.

Station Creek

The Station Creek monitoring site (Figure 3.12) required a different design than the smaller creeks, particularly since the sand depth is greater than 4 m and the water table is shallow all year.

Instruments

Three instruments are being used in the stream to measure water depth, velocity and turbidity. An ISCO water sampler is used to collect samples during stream-flow events. A tipping bucket rainguage is attached to the platform to measure rainfall intensity and totals.

Water depth

The water level instrument at Station Creek differs to those at Wheel and Weany Creeks being a PS700 supplied by Greenspan Australia. This instrument has a closed venting system allowing for improved reliability compared to the vented depth sensors. This sensor also has better immunity to extreme temperature variations than the Dataflow sensor. The full-scale range of the PS700 is 5 meters.

Turbidity

The turbidity instrument used at Station creep is an Analite NEP180 180 degree backscatter fibre optic nephelometer (McVan Instruments). This instrument has a full-scale range of 10,000 NTU.

Other instruments

The rest of the system is similar to that used at Weany and Wheel Creeks.

Figure 3.12: Station Creek instruments in the stream, with 3 m high platform in the background.

Infrastructure and installation

At Station Creek a series of four pipes were jack hammered as deep as possible to support the instruments. This was done by sharpening one end of 2 m sections of 2 inch medium wall, galvanized pipe and pushing them in with the jack hammer, then welding on another 2 m section and hammering that in. The result was four pipes in a square arrangement at a depth of 3.5 – 4 m (Figure 3.13). The pipes to the sides were then cut off to be below the streambed for burying, the front pipe was cut at 300 mm above the surface and the back pipe was cut at 600 mm above the surface.

Straps ("pole ties") were manufactured from 75 x 6 mm flat mild steel with 2" tight fit clamps to suit the distances between the poles to tie the structure together, as shown in Figure 3.13 and Figure 3.14. An "angle strap" tie plate (Figure 3.15) was manufactured to help support the back pipe and deflect debris.

Figure 3.13: Instrument supports in Station Creek

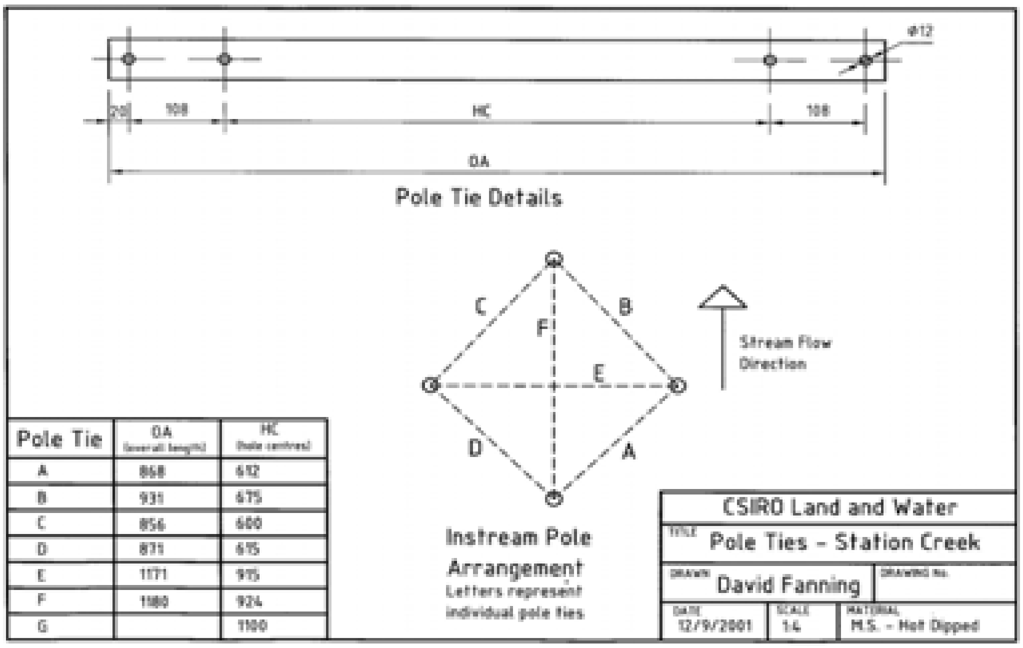


Figure 3.14: Drawing of pole ties for Station Creek

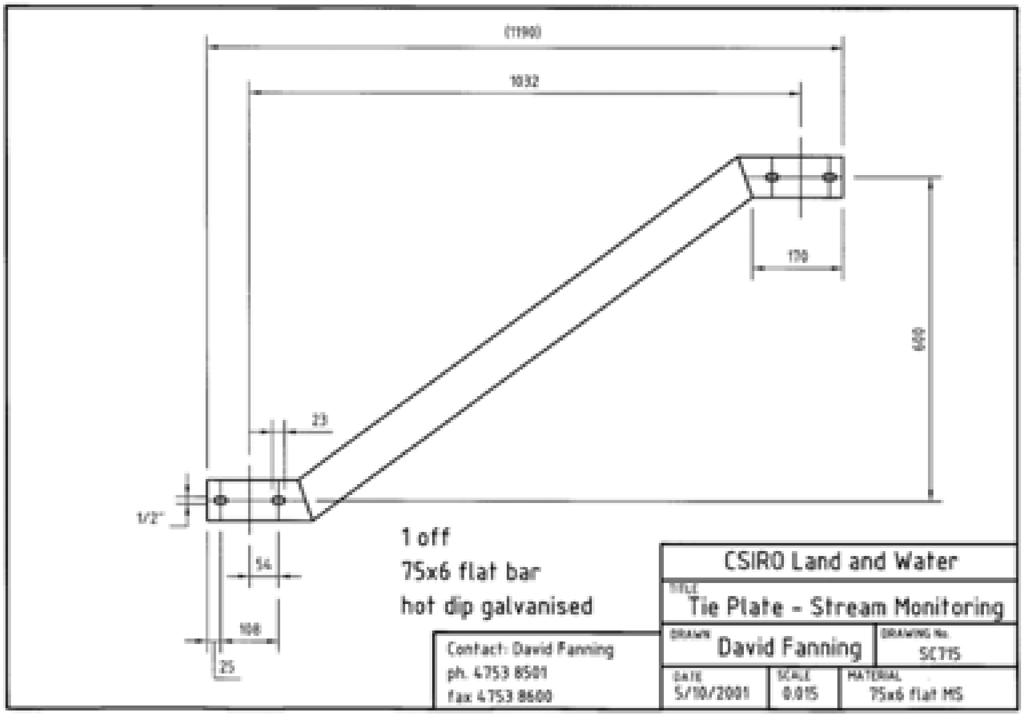


Figure 3.15: Drawing of tie plate for Station Creek

Support frames to attach and protect the instruments were designed, manufactured and galvanised, as shown in Figure 3.12, and the drawings in Figures 3.16 and 3.17. The frames were held in place with 2" tight fit clamps and tack welded to prevent turning.

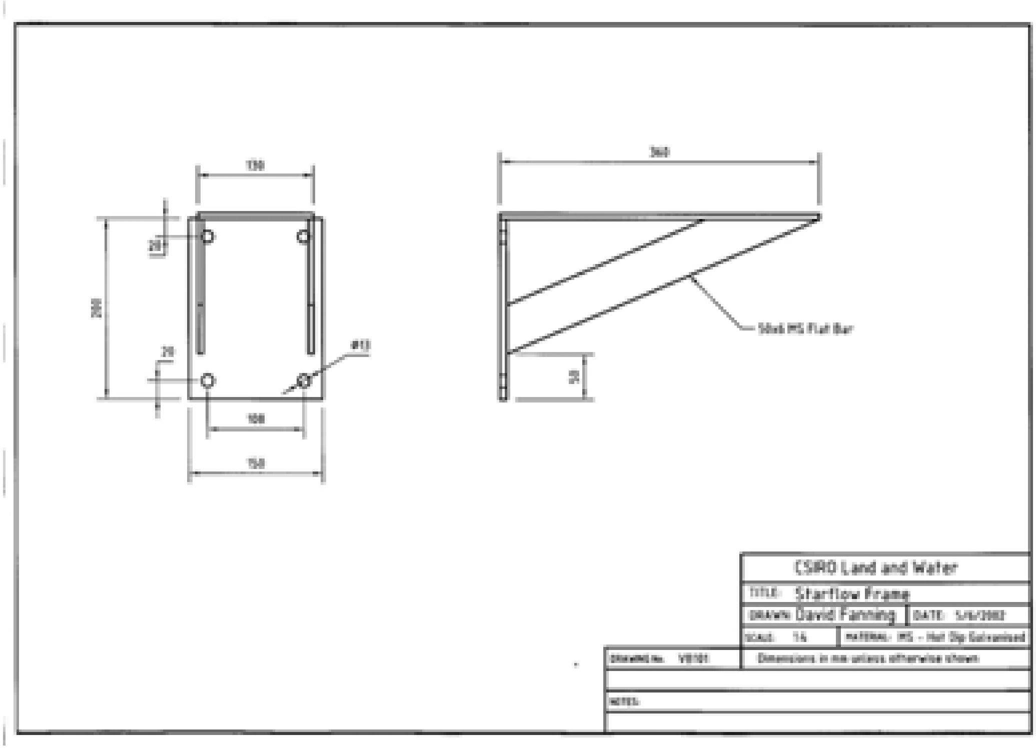


Figure 3.16: Drawing of support frame for the velocity meter (0.5 x scale)

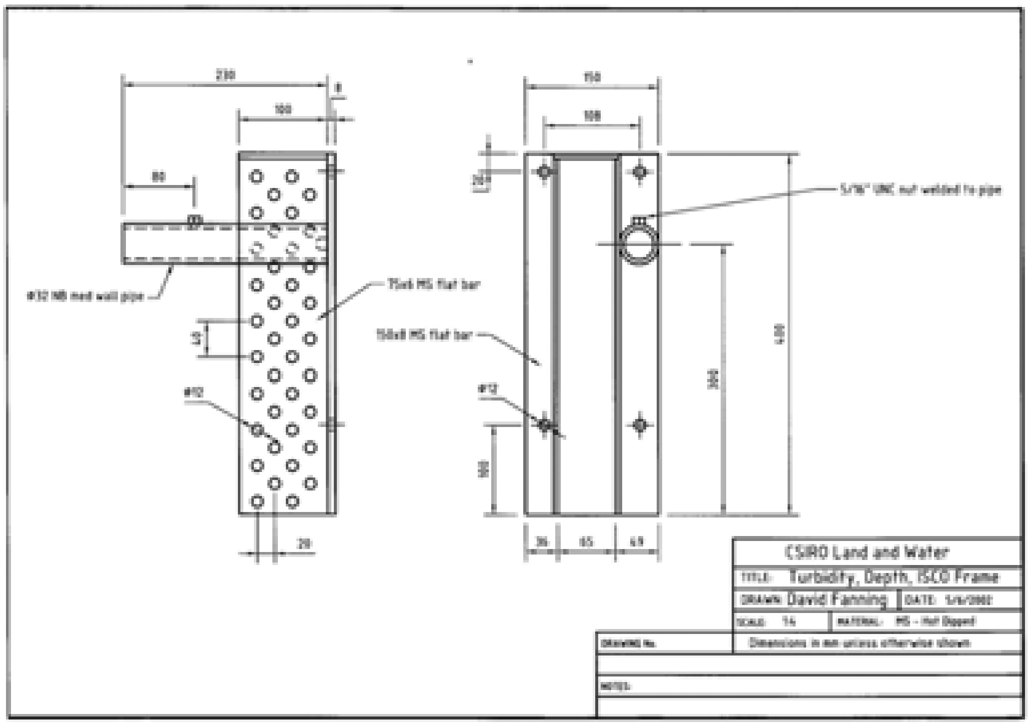


Figure 3.17: Drawing of support frame for velocity and depth meters, and ISCO uptake (0.5 x scale)

Burdekin River

In the Burdekin River two turbidity meters were deployed, to be used in conjunction with the existing NR&M gauging station. With permission from Queensland Rail these were bolted to the old railway bridge at Macrossan. The instruments are protected inside stainless steel housings, as shown in Figures 3.18 and 3.19, and fixed at heights of 1 m and 3 m above the streambed. The housings were fixed to the bridge support using chemical anchors, since they create no expansion forces and once cured the resin provides a stress free bond with the surrounding materials.

The instruments used at the Macrossan railway bridge were two Greenspan logging TS300 Turbidity meters (Greenspan Australia). These combination logger and sensor units have an integral battery pack that can supply power for extended periods of time (greater than 6 months). This allows for fully self-contained immersed operation. The full-scale range of these units is 2500NTU. The logging regime was set to log every 20 minutes and to event mode log every 10 minutes if the turbidity measurement had changed by more than 10NTU.

Figure 3.18: Turbidity meter inside the stainless steel housing, fixed to the old railway bridge at Macrossan on the Burdekin River.

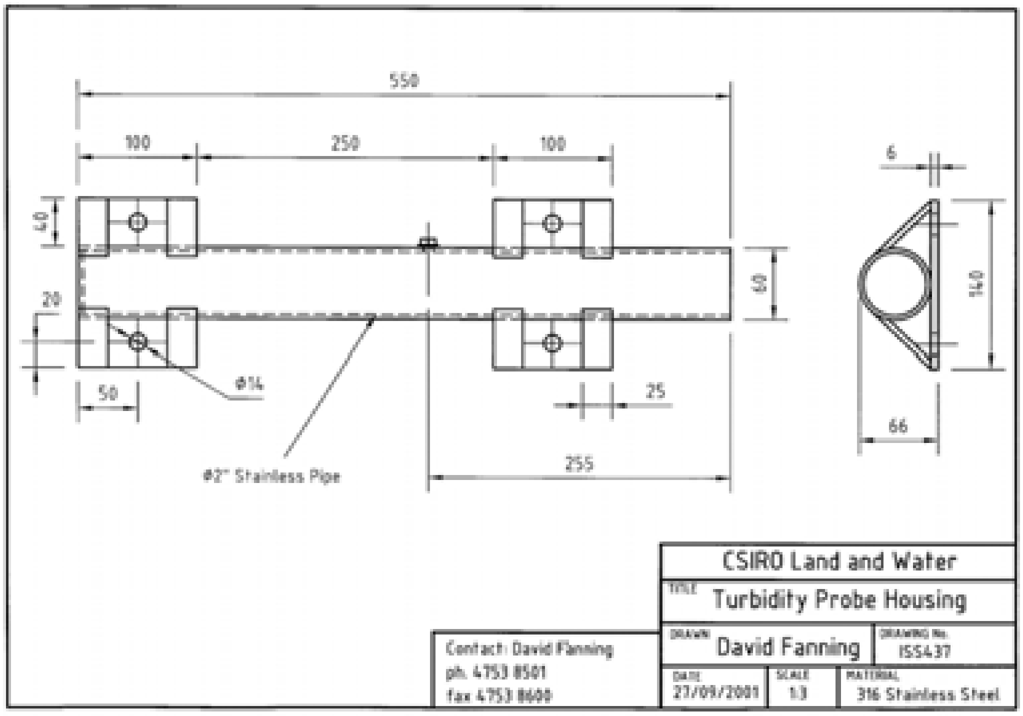
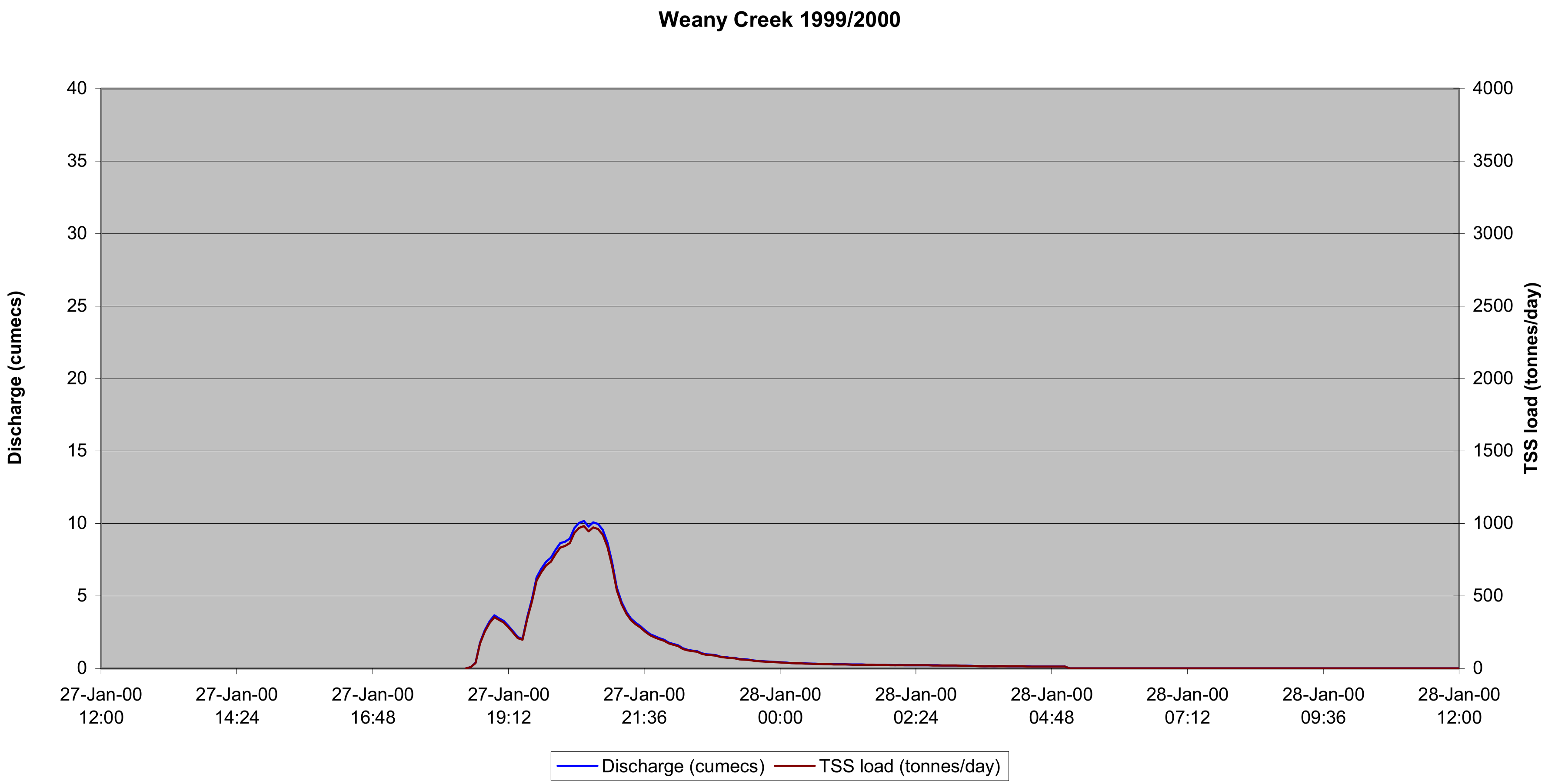


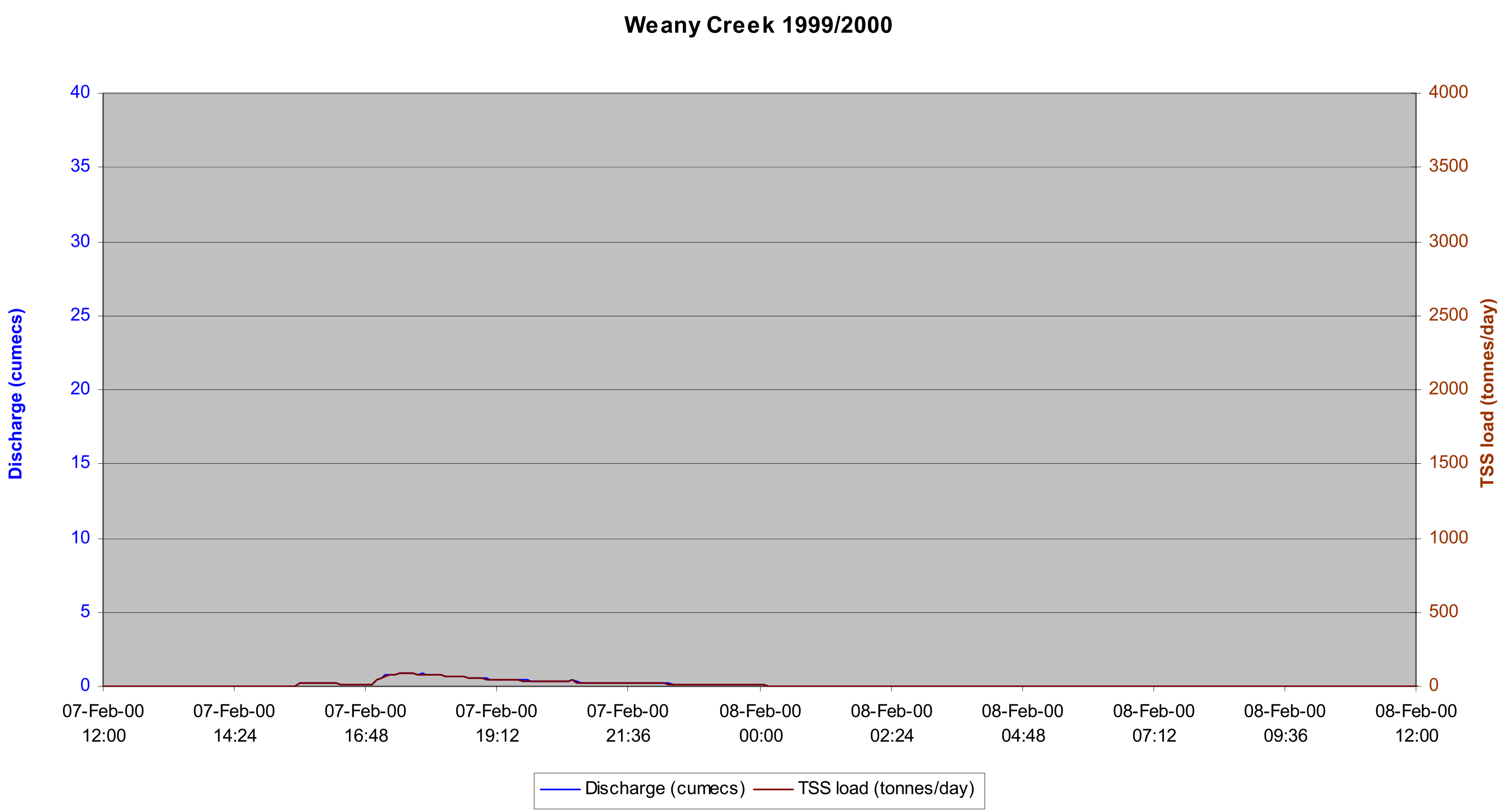
Figure 3.19: Drawing of the housing for the Greenspan turbidity meters.

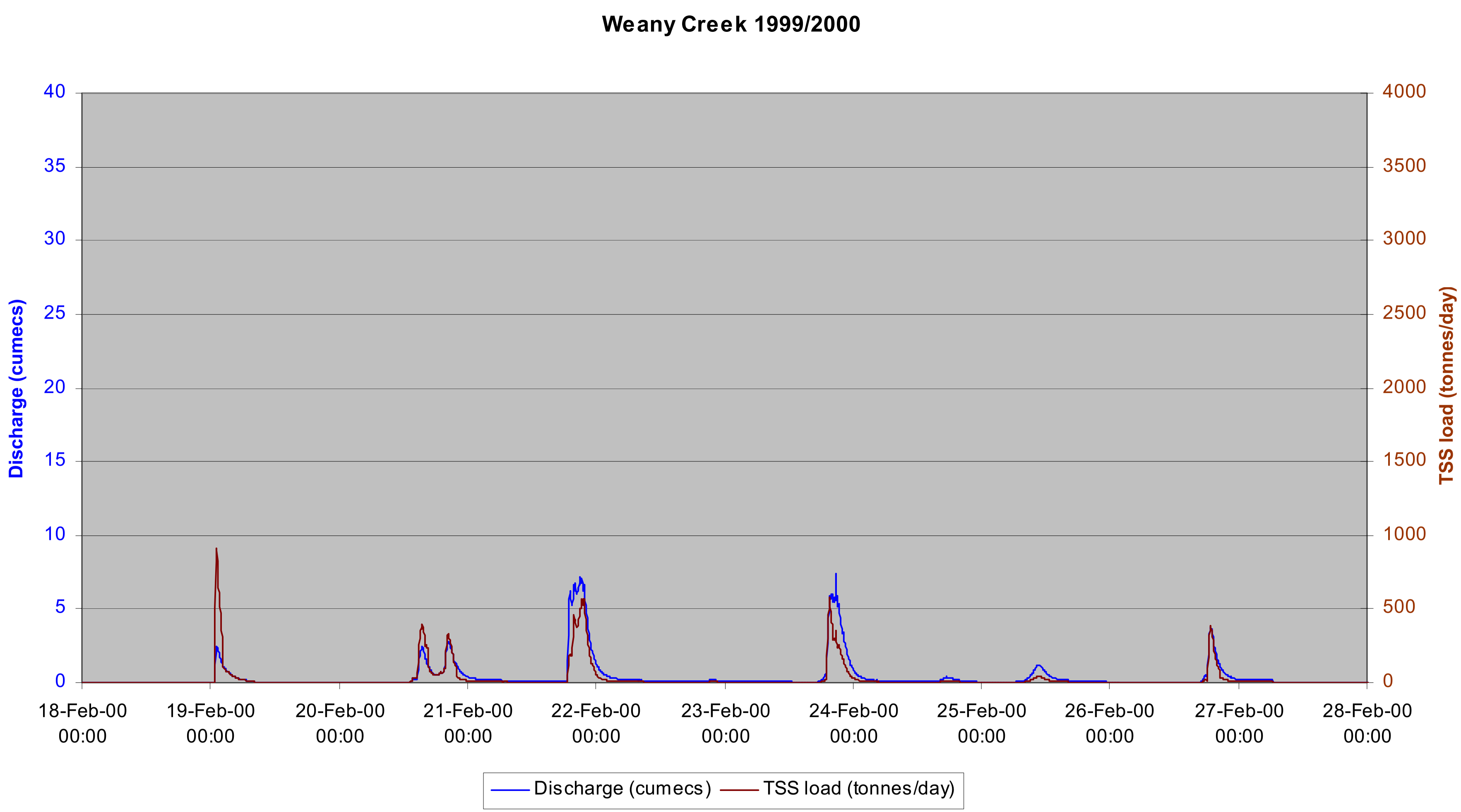
Appendix 4. Compilation of stream gauging data for the period 1999-2002 for the MLA gauging sites, Upper Burdekin

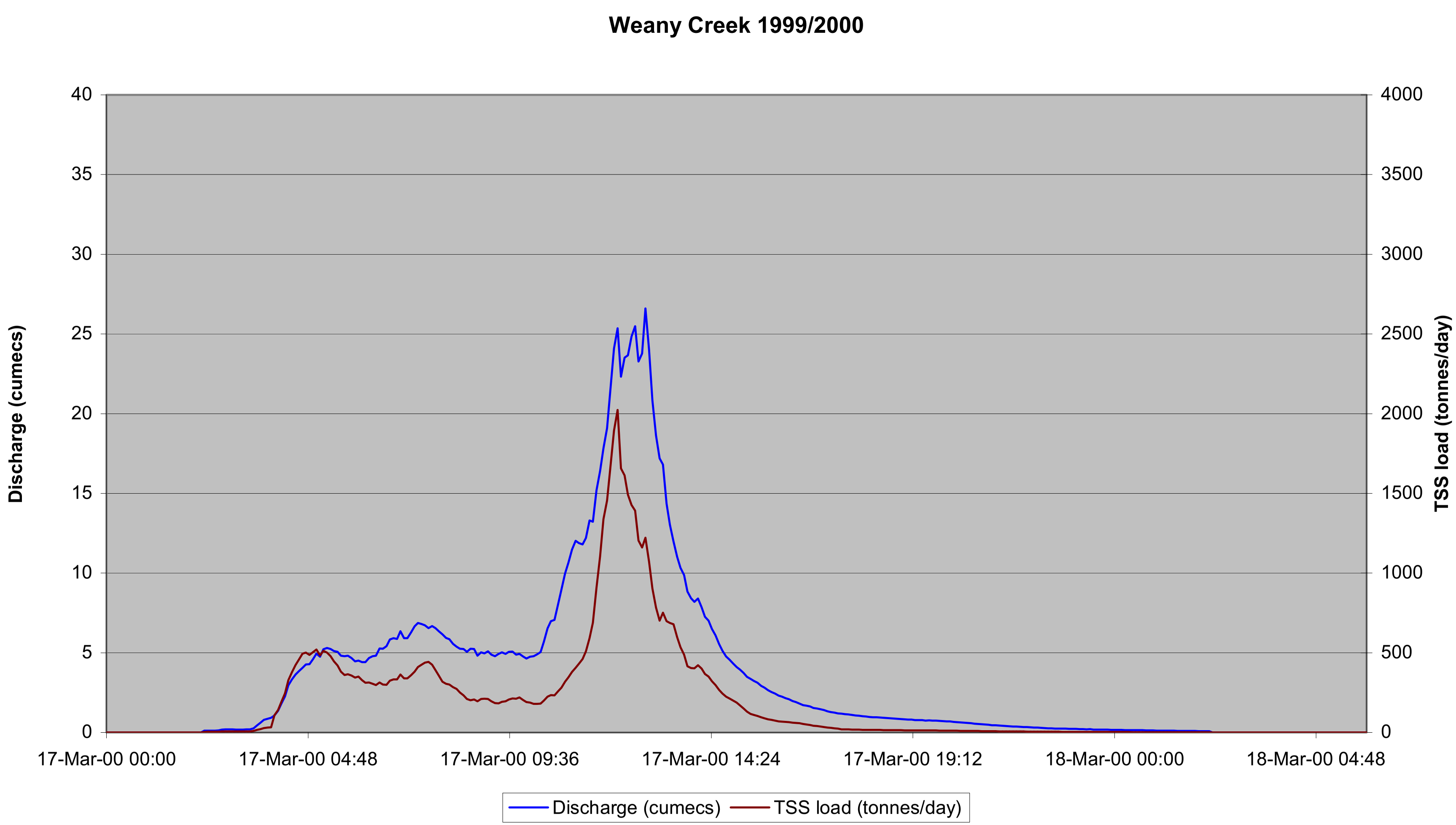
David Post, CSIRO Land & Water, Townsville

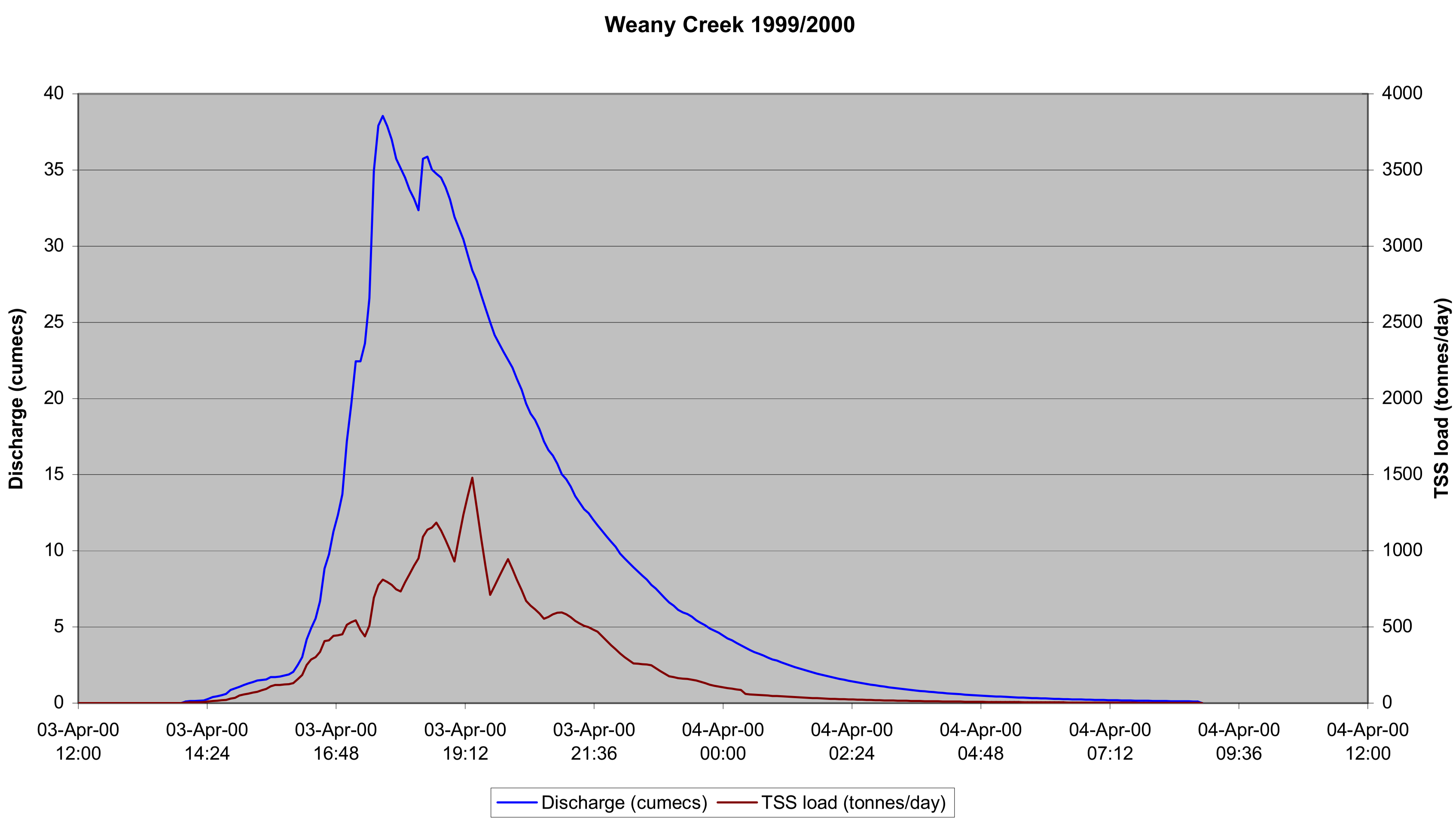
The purpose of this appendix is to provide a compilation of all recorded flow events for the Weany, Wheel and Station Creek gauging stations. Details on the instrumentation are provided in Appendix 3, and the methodology used to derive flow and sediment discharge is discussed in Chapter 5, Volume I. Data in this appendix is presented in the form of hydrographs and sedigraphs.


Weany Creek 1999/2000
Discharge (cumecs)
TSS load (tonnes/day)
0
5
10
15
20
25
30
35
40
0
500
1000
1500
2000
2500
3000
3500
4000
27-Jan-00 12:00
27-Jan-00 14:24
27-Jan-00 16:48
27-Jan-00 19:12
27-Jan-00 21:36
28-Jan-00 00:00
28-Jan-00 02:24
28-Jan-00 04:48
28-Jan-00 07:12
28-Jan-00 09:36
28-Jan-00 12:00
Discharge (cumecs)
TSS load (tonnes/day)

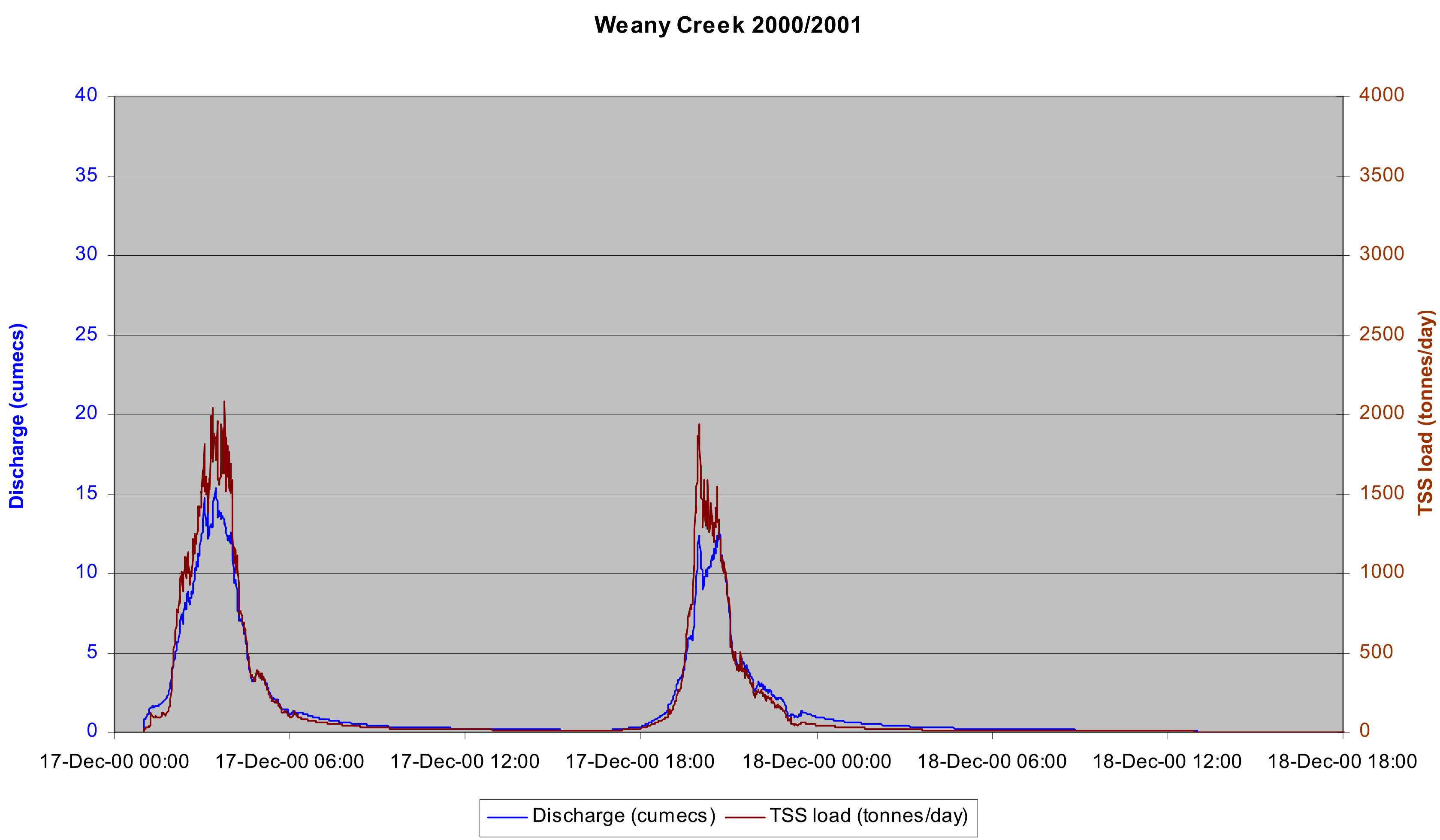

Weany Creek 1999/2000
Discharge (cumecs)
TSS load (tonnes/day)
0
5
10
15
20
25
30
35
40
0
500
1000
1500
2000
2500
3000
3500
4000
07-Feb-00 12:00
07-Feb-00 14:24
07-Feb-00 16:48
07-Feb-00 19:12
07-Feb-00 21:36
08-Feb-00 00:00
08-Feb-00 02:24
08-Feb-00 04:48
08-Feb-00 07:12
08-Feb-00 09:36
08-Feb-00 12:00
Discharge (cumecs)
TSS load (tonnes/day)

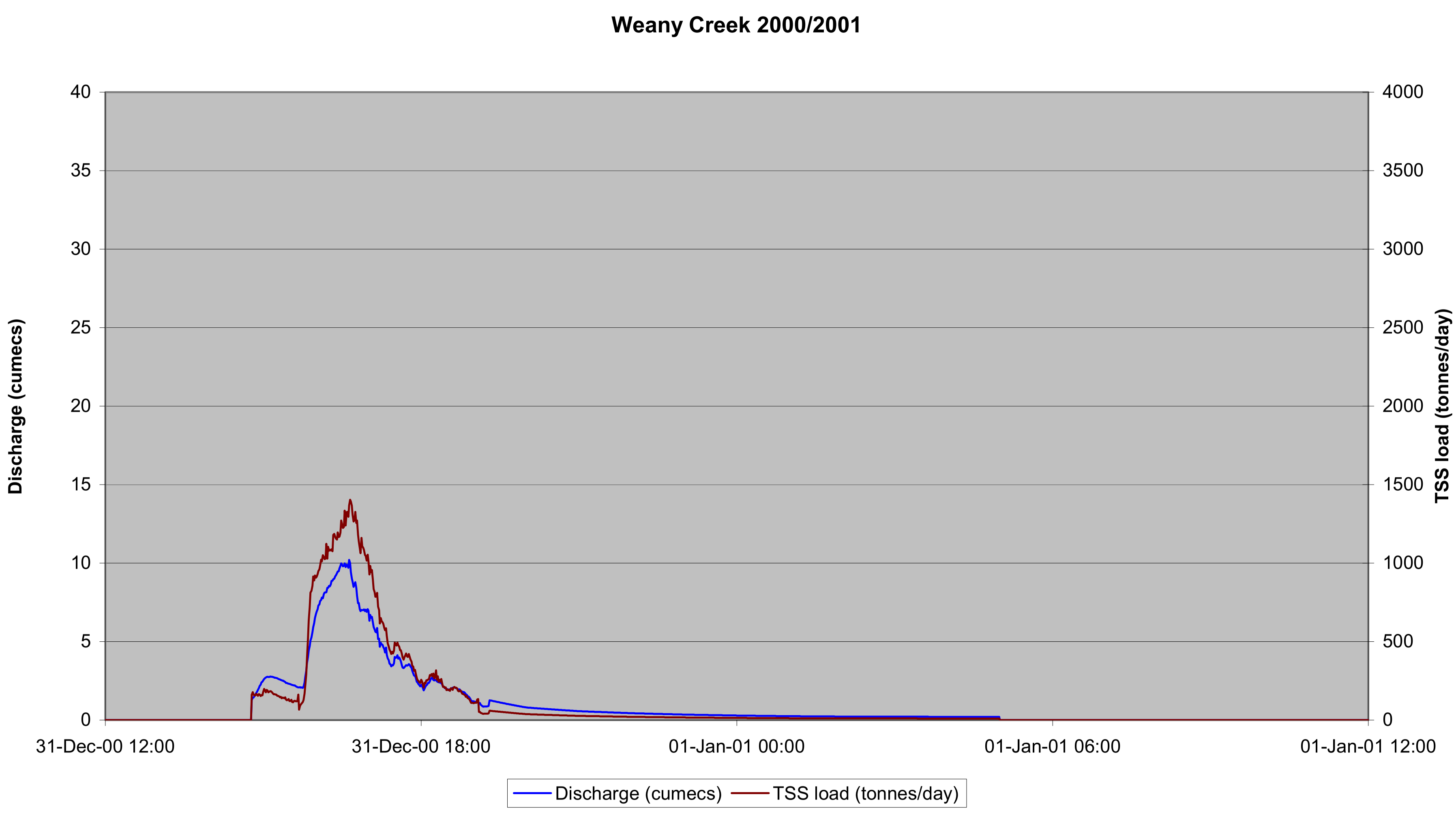

Weany Creek 1999/2000
Discharge (cumecs)
TSS load (tonnes/day)
0
5
10
15
20
25
30
35
40
500
1000
1500
2000
2500
3000
3500
4000
18-Feb-00 00:00
19-Feb-00 00:00
20-Feb-00 00:00
21-Feb-00 00:00
22-Feb-00 00:00
23-Feb-00 00:00
24-Feb-00 00:00
25-Feb-00 00:00
26-Feb-00 00:00
27-Feb-00 00:00
28-Feb-00 00:00
Discharge (cumecs)
TSS load (tonnes/day)

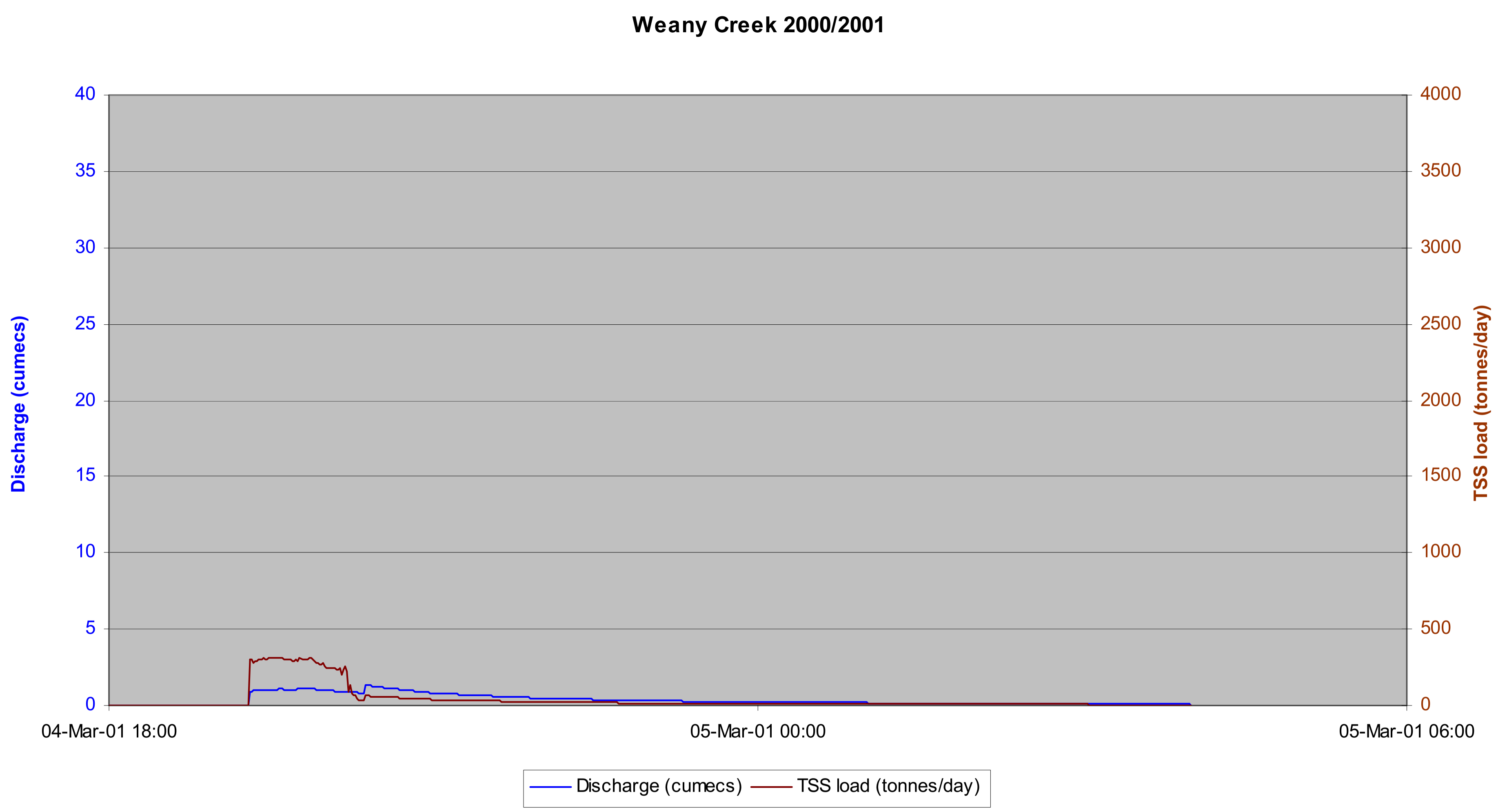

Weany Creek 1999/2000
Discharge (cumecs)
TSS load (tonnes/day)
40
35
30
25
20
15
10
5
0
4000
3500
3000
2500
2000
1500
1000
500
0
17-Mar-00 00:00
17-Mar-00 04:48
17-Mar-00 09:36
17-Mar-00 14:24
17-Mar-00 19:12
18-Mar-00 00:00
18-Mar-00 04:48
Discharge (cumecs)
TSS load (tonnes/day)



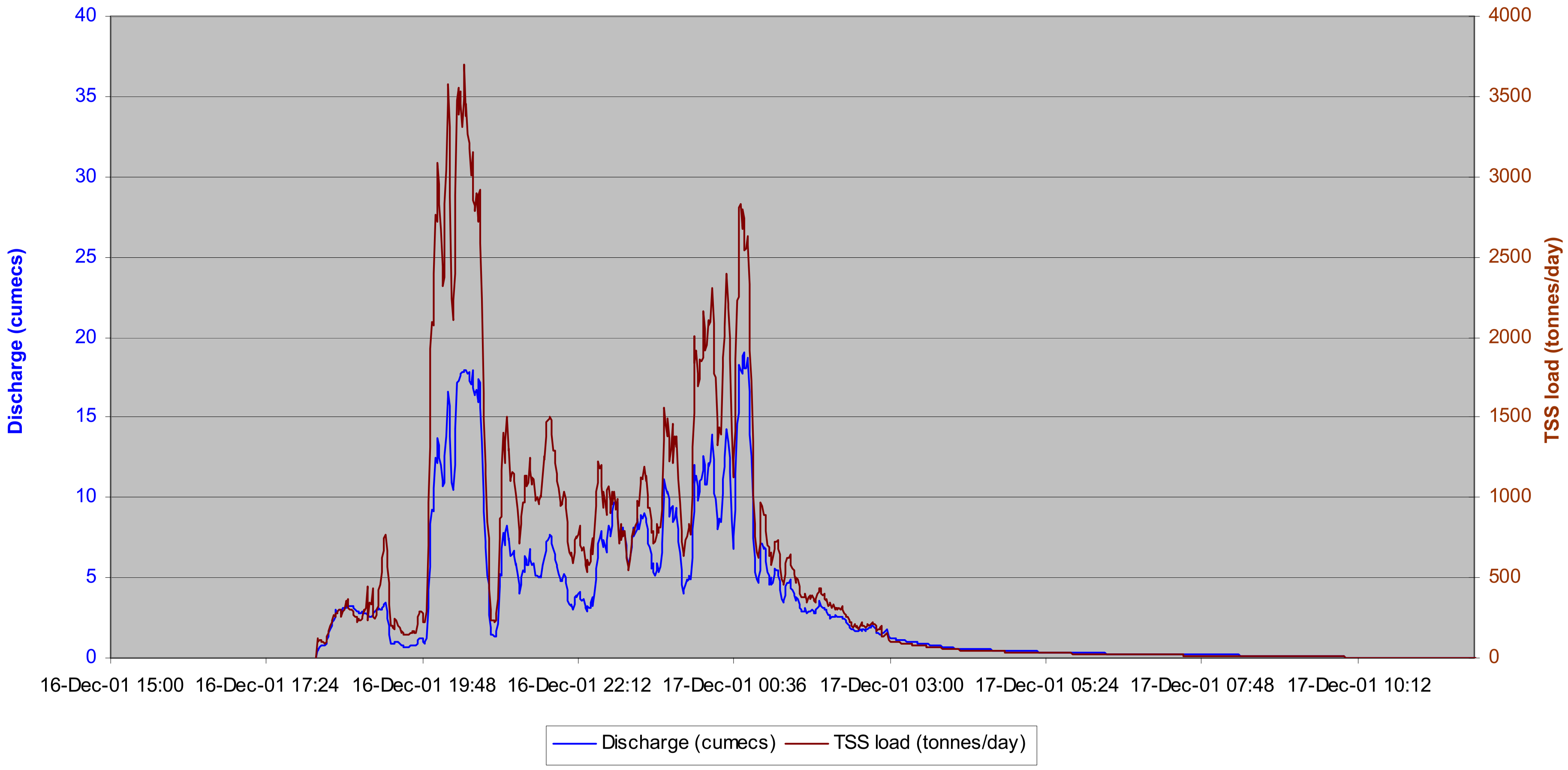
Weany Creek 1999/2000
Discharge (cumecs)
40
35
30
25
20
15
10
5
0
TSS load (tonnes/day)
4000
3500
3000
2500
2000
1500
1000
500
0
03-Apr-00 12:00
03-Apr-00 14:24
03-Apr-00 16:48
03-Apr-00 19:12
03-Apr-00 21:36
04-Apr-00 00:00
04-Apr-00 02:24
04-Apr-00 04:48
04-Apr-00 07:12
04-Apr-00 09:36
04-Apr-00 12:00
Discharge (cumecs)
TSS load (tonnes/day)

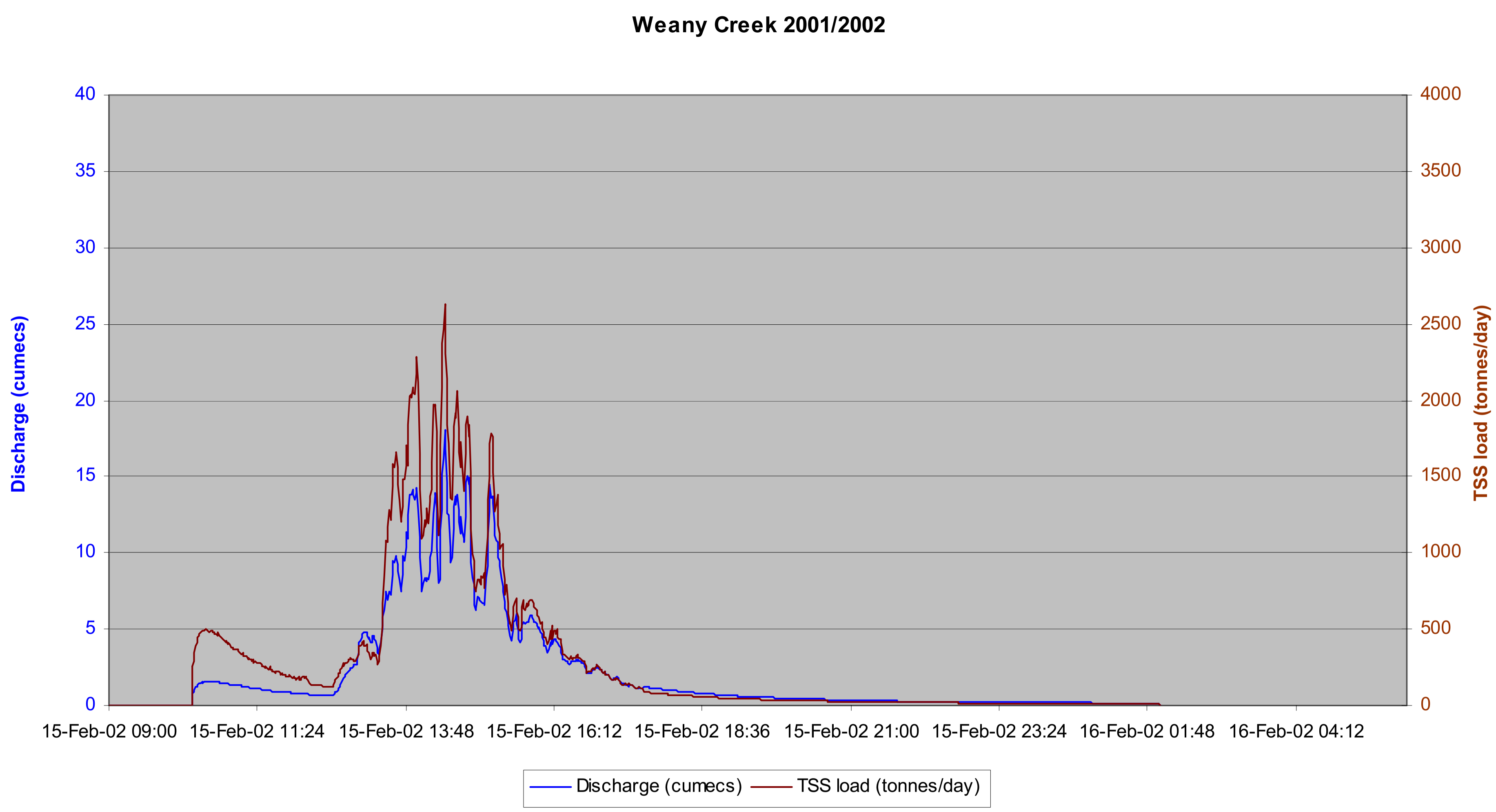

Weany Creek 2000/2001
Discharge (cumecs)
TSS load (tonnes/day)
40
35
30
25
20
15
10
5
0
4000
3500
3000
2500
2000
1500
1000
500
0
17-Dec-00 00:00
17-Dec-00 06:00
17-Dec-00 12:00
17-Dec-00 18:00
18-Dec-00 00:00
18-Dec-00 06:00
18-Dec-00 12:00
18-Dec-00 18:00
Discharge (cumecs)
TSS load (tonnes/day)

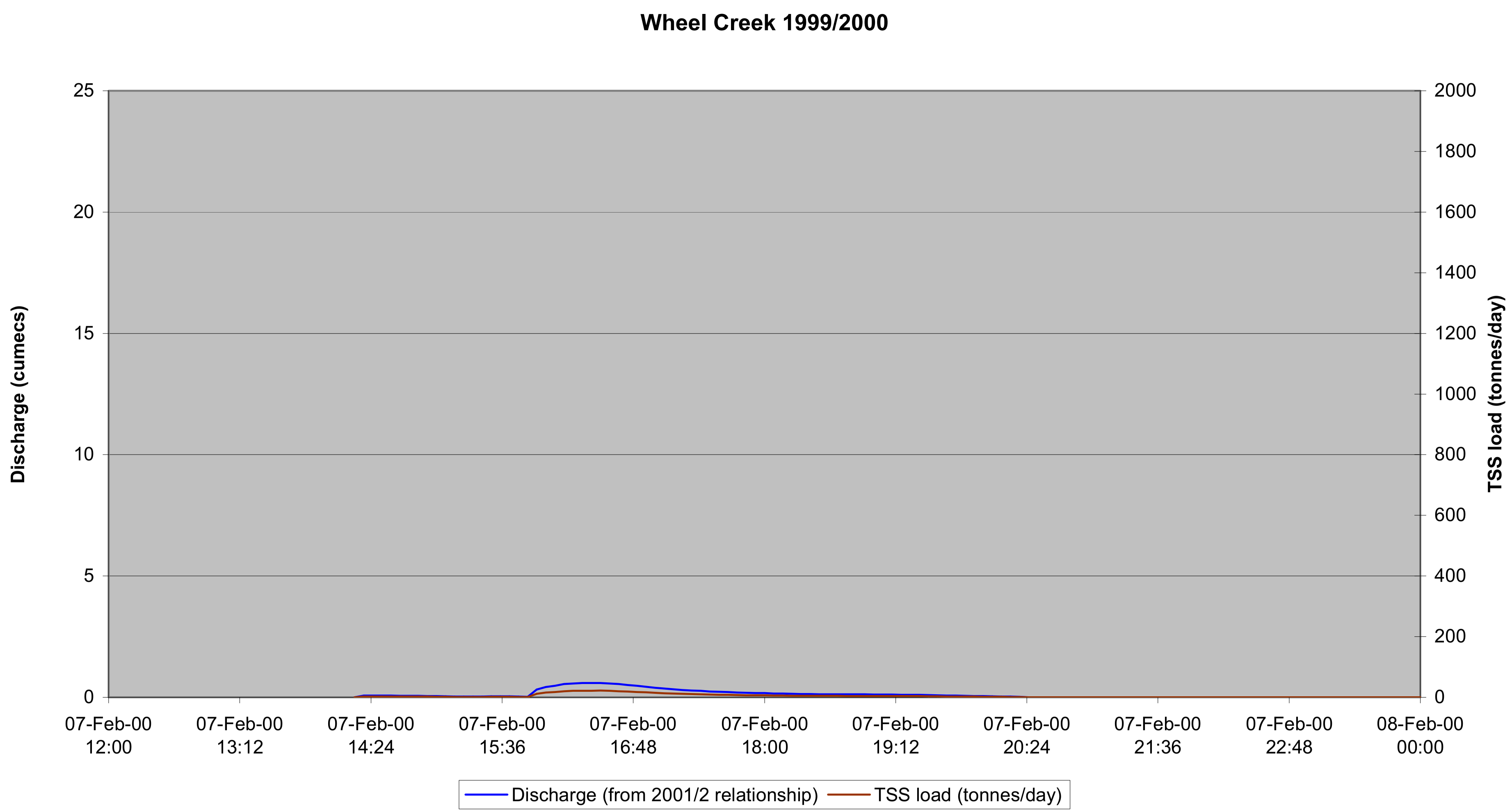

Weany Creek 2000/2001
Discharge (cumecs)
TSS load (tonnes/day)
40
35
30
25
20
15
10
5
0
4000
3500
3000
2500
2000
1500
1000
500
0
31-Dec-00 12:00
31-Dec-00 18:00
01-Jan-01 00:00
01-Jan-01 06:00
01-Jan-01 12:00
Discharge (cumecs)
TSS load (tonnes/day)

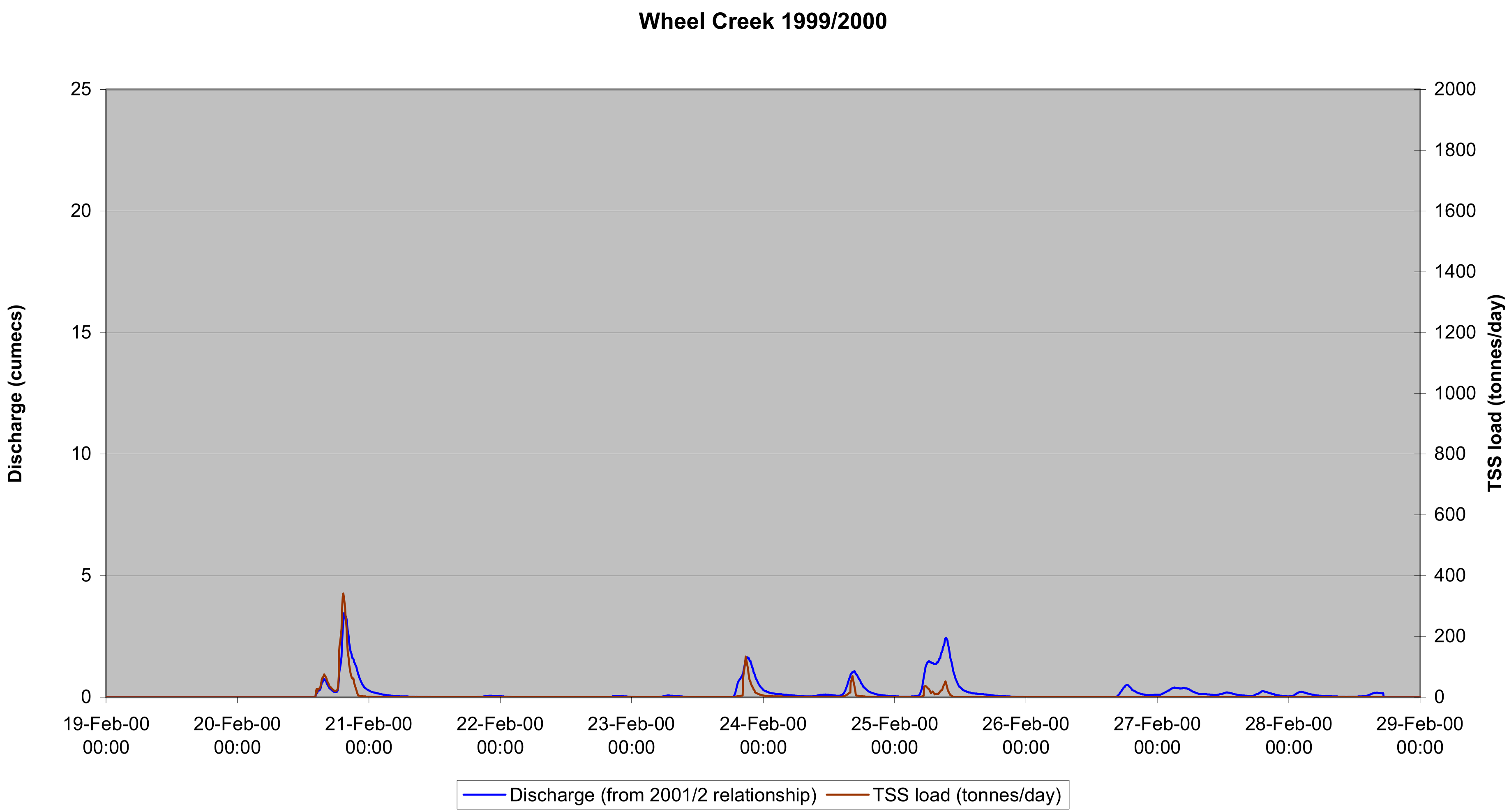

Weany Creek 2000/2001
Discharge (cumecs)
TSS load (tonnes/day)
40
35
30
25
20
15
10
5
0
4000
3500
3000
2500
2000
1500
1000
500
0
04-Mar-01 18:00
05-Mar-01 00:00
05-Mar-01 06:00
Discharge (cumecs)
TSS load (tonnes/day)

Weany Creek 2001/2002

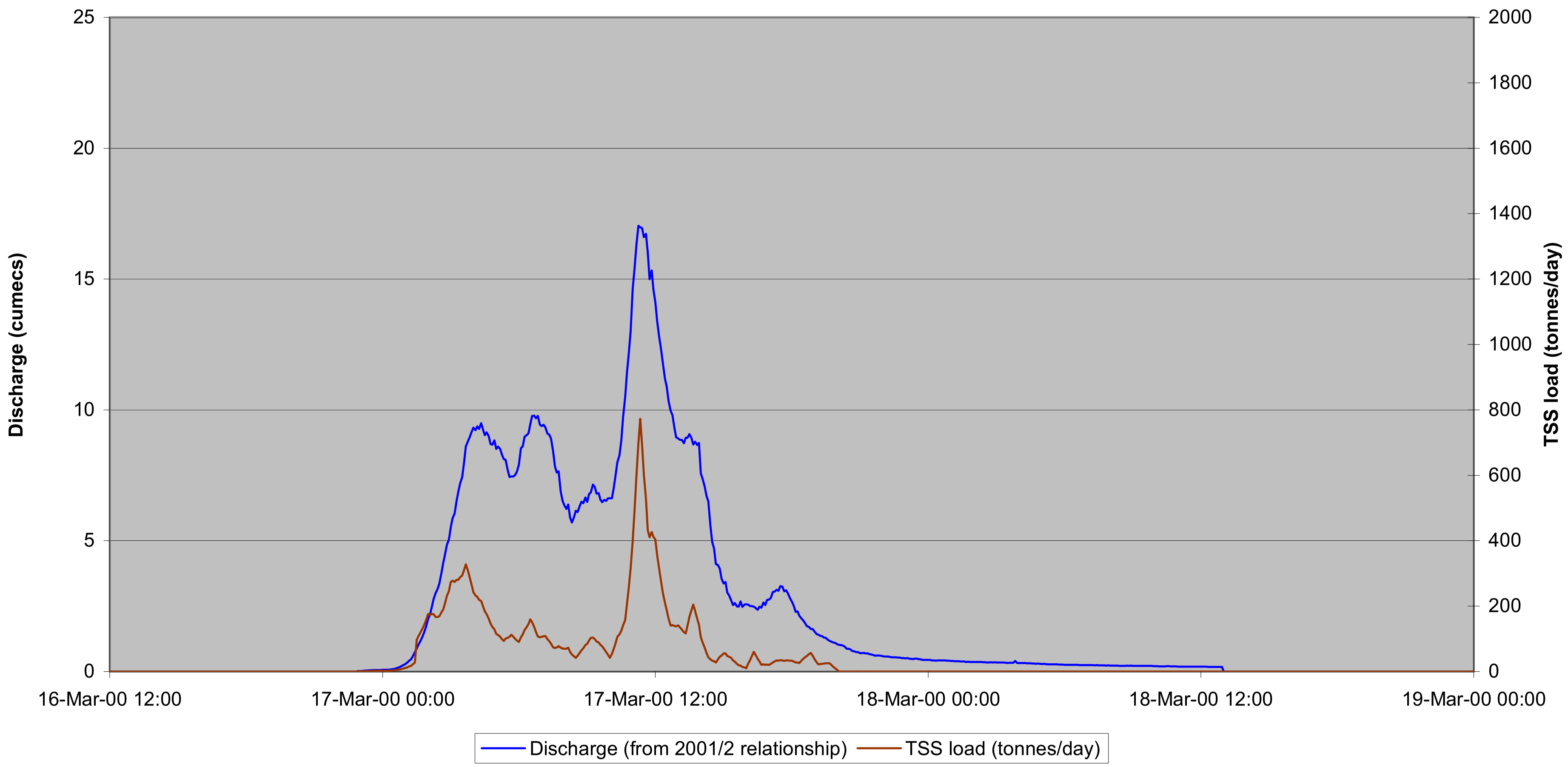


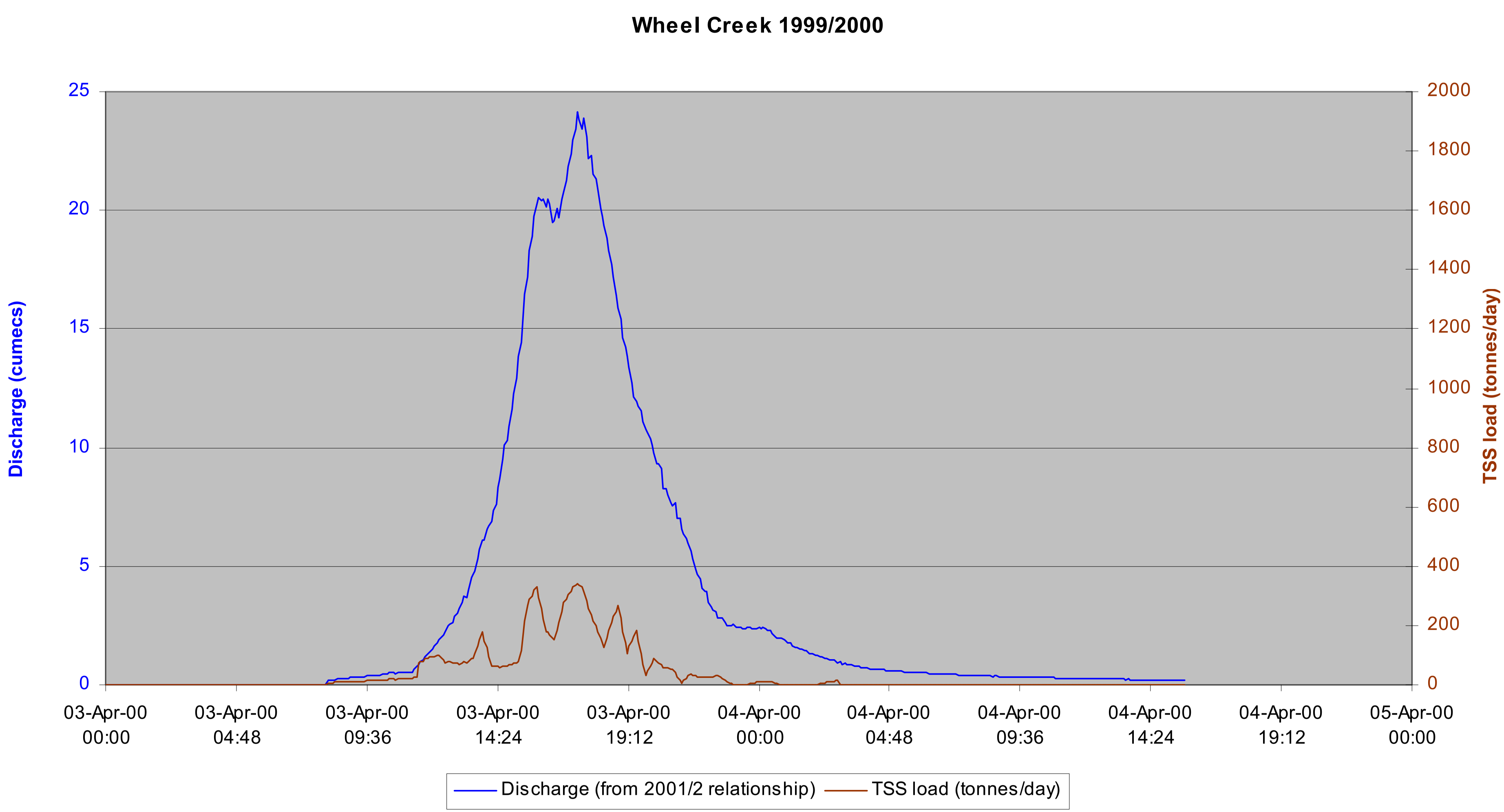

Weany Creek 2001/2002
Discharge (cumecs)
TSS load (tonnes/day)
0
5
10
15
20
25
30
35
40
0
500
1000
1500
2000
2500
3000
3500
4000
15-Feb-02 09:00
15-Feb-02 11:24
15-Feb-02 13:48
15-Feb-02 16:12
15-Feb-02 18:36
15-Feb-02 21:00
15-Feb-02 23:24
16-Feb-02 01:48
16-Feb-02 04:12
Discharge (cumecs)
TSS load (tonnes/day)

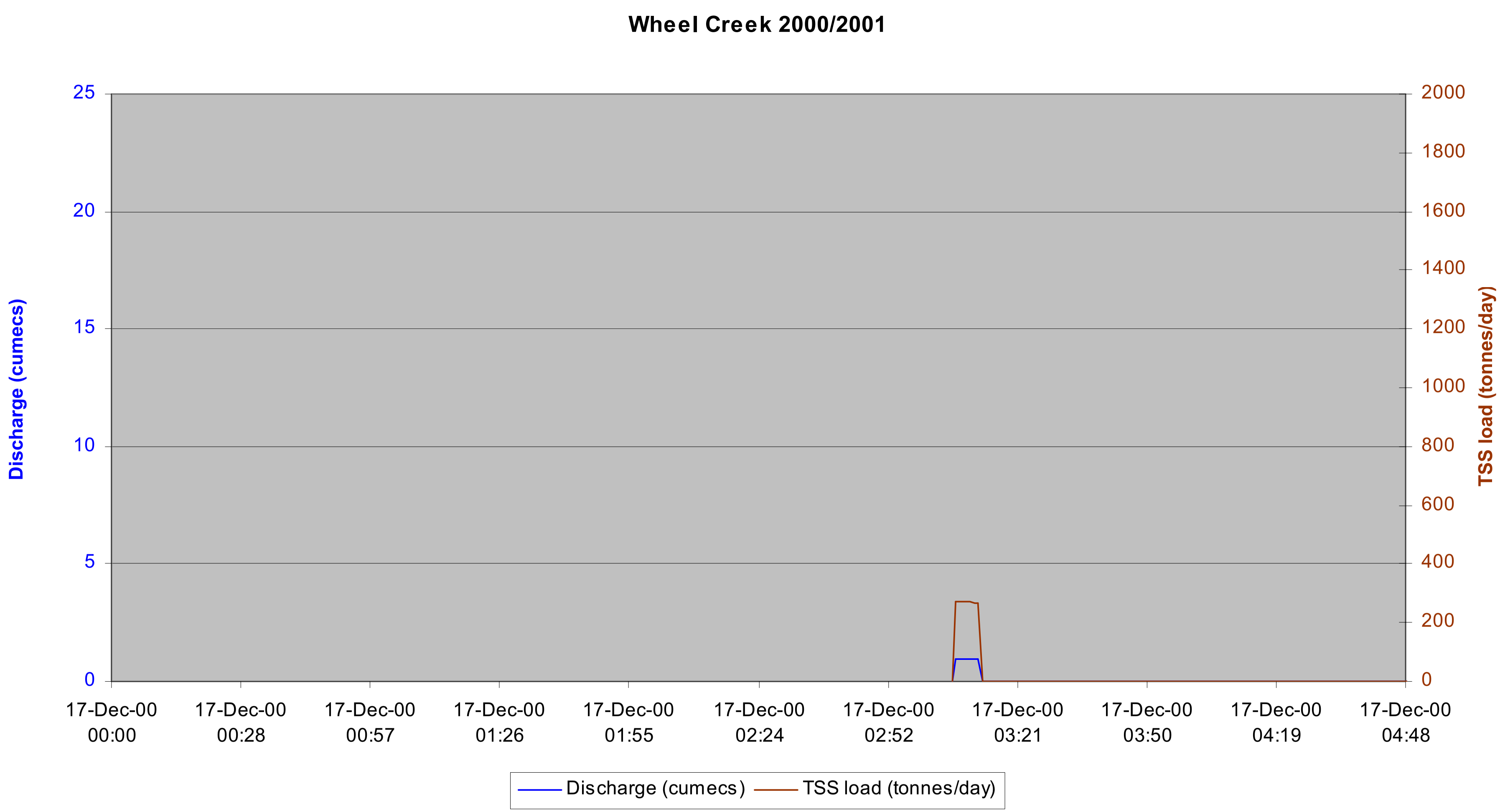

Wheel Creek 1999/2000
Discharge (cumecs)
TSS load (tonnes/day)
25
20
15
10
5
0
2000
1800
1600
1400
1200
1000
800
600
400
200
0
07-Feb-00 12:00
07-Feb-00 13:12
07-Feb-00 14:24
07-Feb-00 15:36
07-Feb-00 16:48
07-Feb-00 18:00
07-Feb-00 19:12
07-Feb-00 20:24
07-Feb-00 21:36
07-Feb-00 22:48
08-Feb-00 00:00
Discharge (from 2001/2 relationship)
TSS load (tonnes/day)

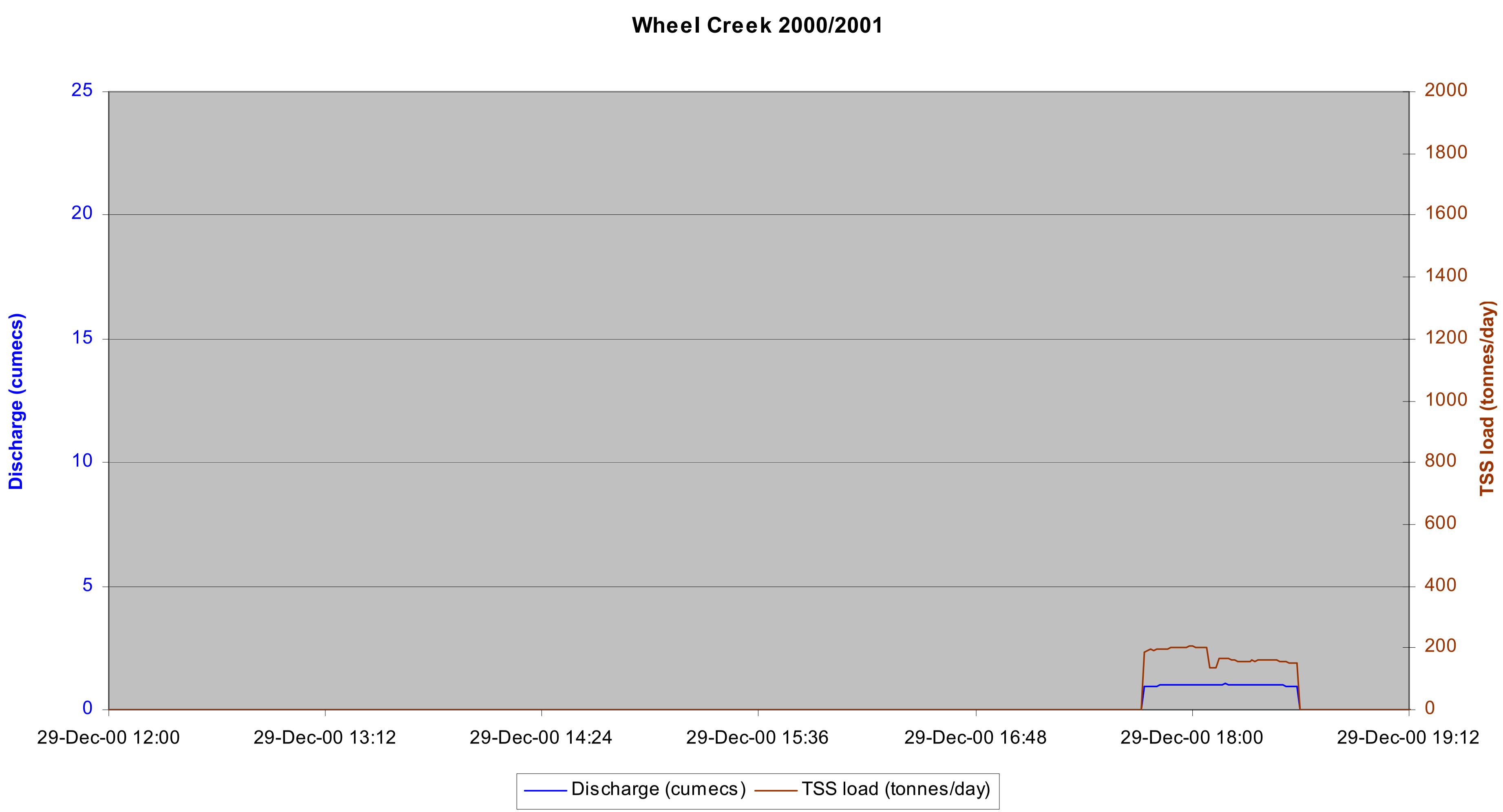

Wheel Creek 1999/2000
Discharge (cumecs)
TSS load (tonnes/day)
0
5
10
15
20
25
0
200
400
600
800
1000
1200
1400
1600
1800
2000
19-Feb-00 00:00
20-Feb-00 00:00
21-Feb-00 00:00
22-Feb-00 00:00
23-Feb-00 00:00
24-Feb-00 00:00
25-Feb-00 00:00
26-Feb-00 00:00
27-Feb-00 00:00
28-Feb-00 00:00
29-Feb-00 00:00
Discharge (from 2001/2 relationship)
TSS load (tonnes/day)

Wheel Creek 1999/2000

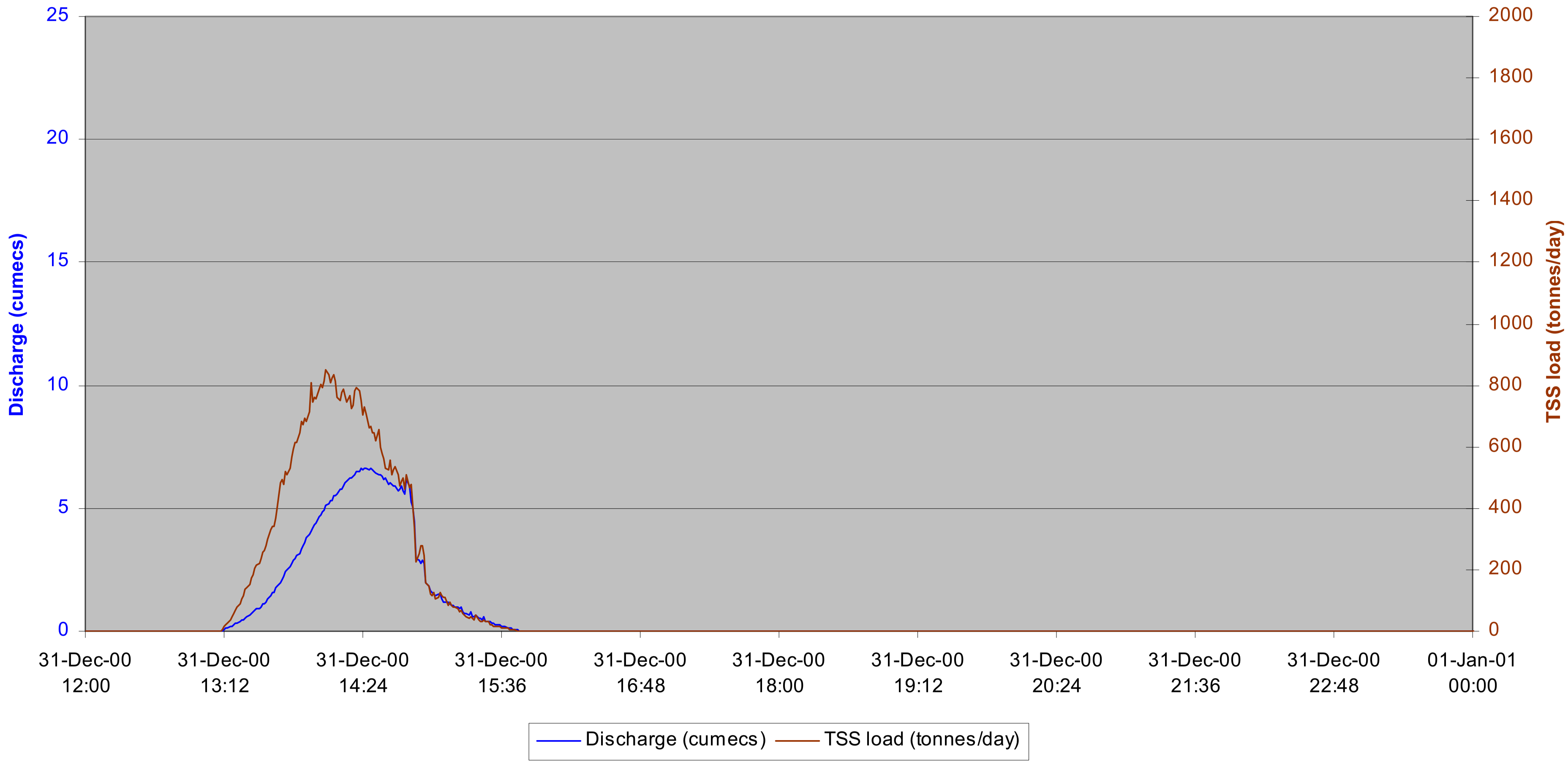


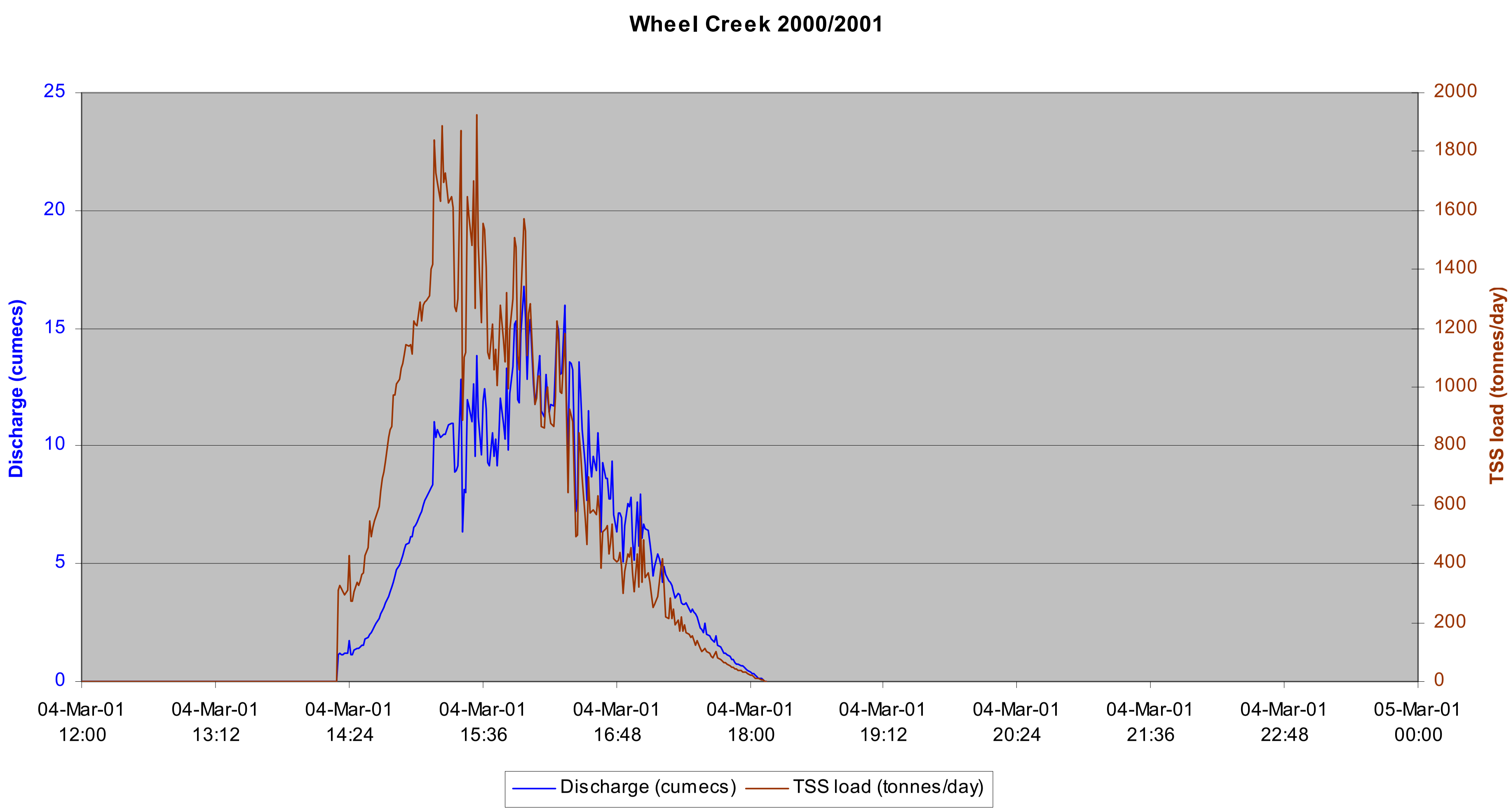

Wheel Creek 1999/2000
Discharge (cumecs)
TSS load (tonnes/day)
25
20
15
10
5
0
2000
1800
1600
1400
1200
1000
800
600
400
200
0
03-Apr-00 00:00
03-Apr-00 04:48
03-Apr-00 09:36
03-Apr-00 14:24
03-Apr-00 19:12
04-Apr-00 00:00
04-Apr-00 04:48
04-Apr-00 09:36
04-Apr-00 14:24
04-Apr-00 19:12
05-Apr-00 00:00
Discharge (from 2001/2 relationship)
TSS load (tonnes/day)


Wheel Creek 2000/2001
Discharge (cumecs)
TSS load (tonnes/day)
25
20
15
10
5
0
2000
1800
1600
1400
1200
1000
800
600
400
200
0
17-Dec-00 00:00
17-Dec-00 00:28
17-Dec-00 00:57
17-Dec-00 01:26
17-Dec-00 01:55
17-Dec-00 02:24
17-Dec-00 02:52
17-Dec-00 03:21
17-Dec-00 03:50
17-Dec-00 04:19
17-Dec-00 04:48
Discharge (cumecs)
TSS load (tonnes/day)

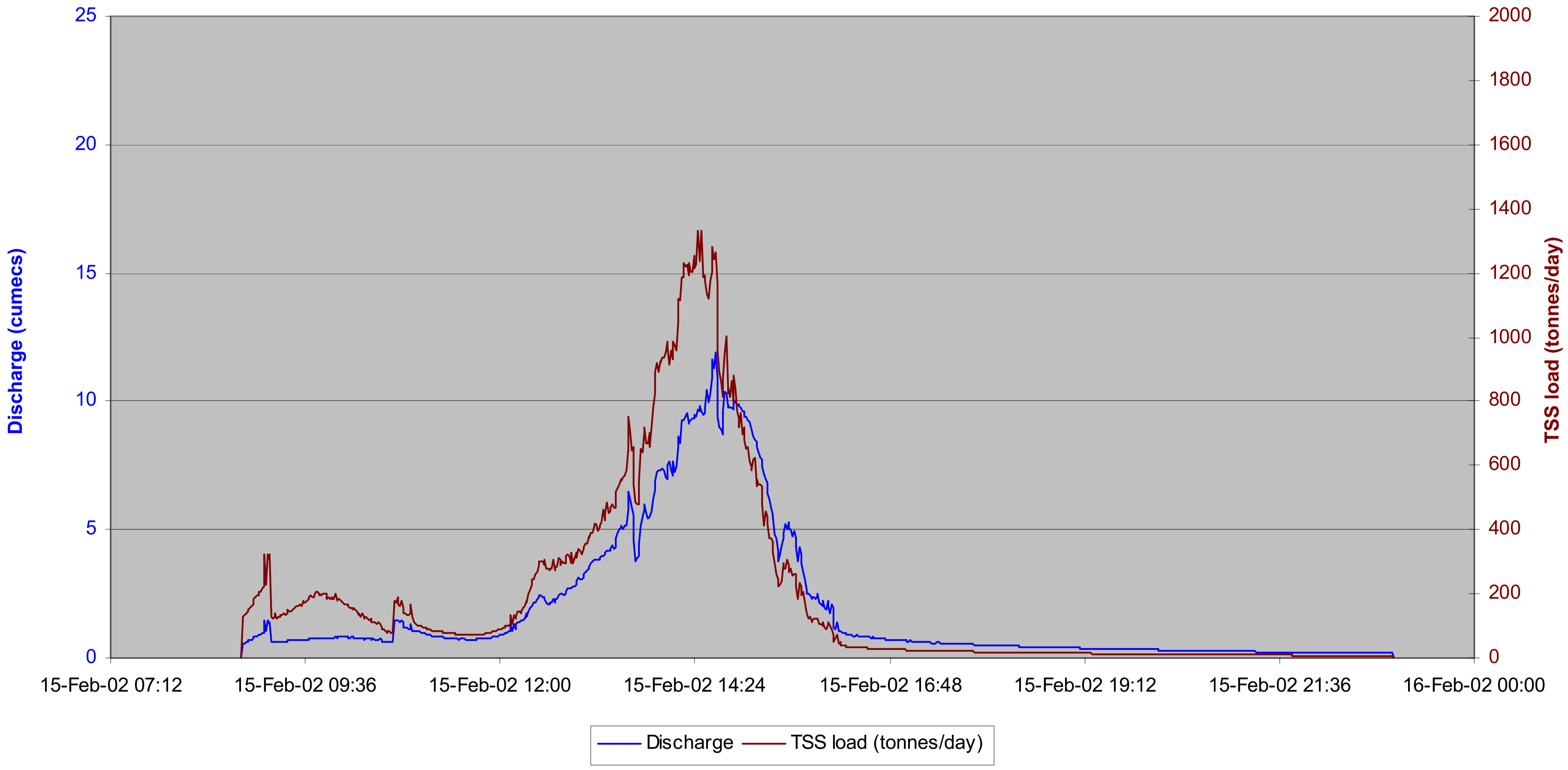

Wheel Creek 2000/2001
Discharge (cumecs)
TSS load (tonnes/day)
25
20
15
10
5
0
2000
1800
1600
1400
1200
1000
800
600
400
200
0
29-Dec-00 12:00
29-Dec-00 13:12
29-Dec-00 14:24
29-Dec-00 15:36
29-Dec-00 16:48
29-Dec-00 18:00
29-Dec-00 19:12
Discharge (cumecs)
TSS load (tonnes/day)

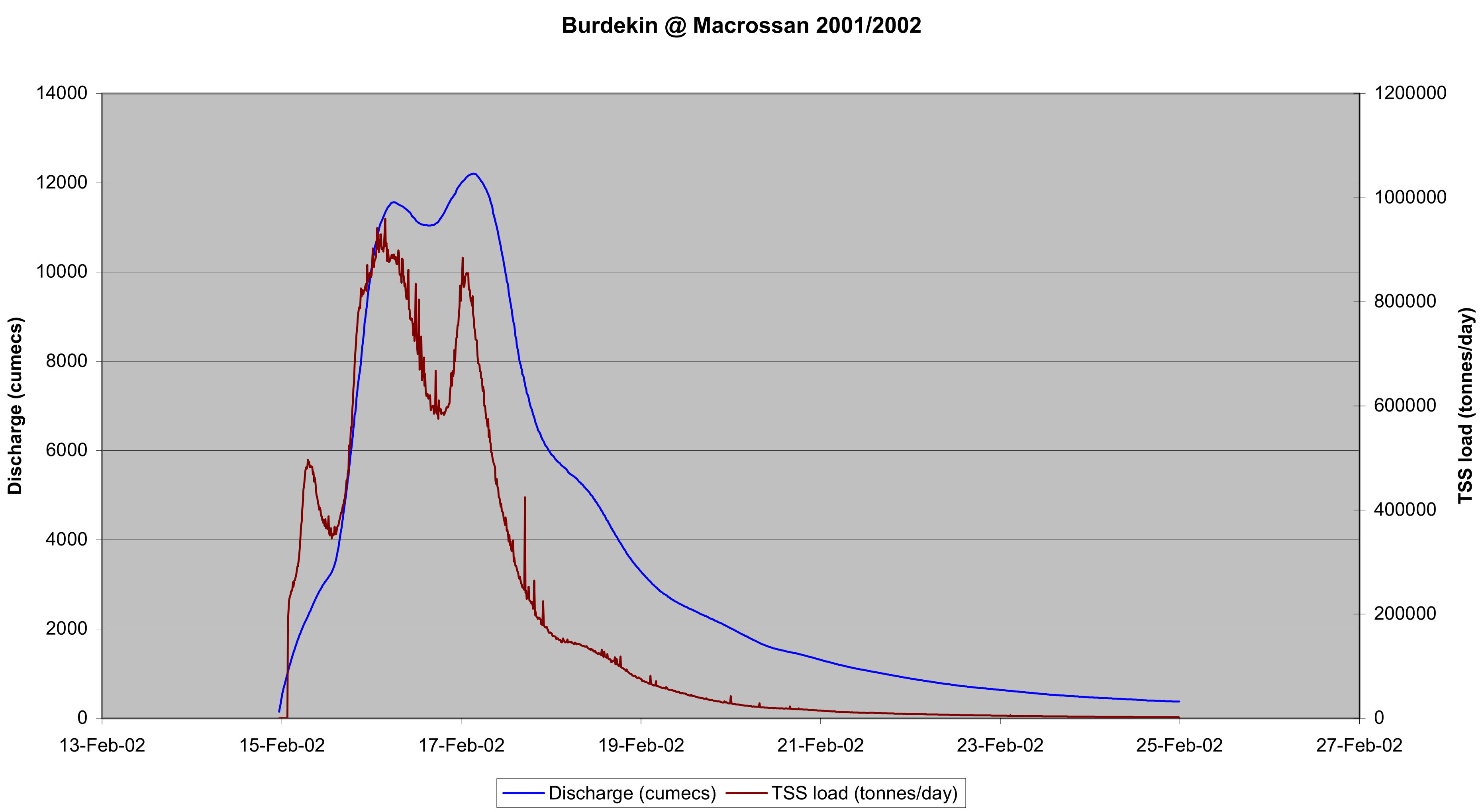
Wheel Creek 2000/2001



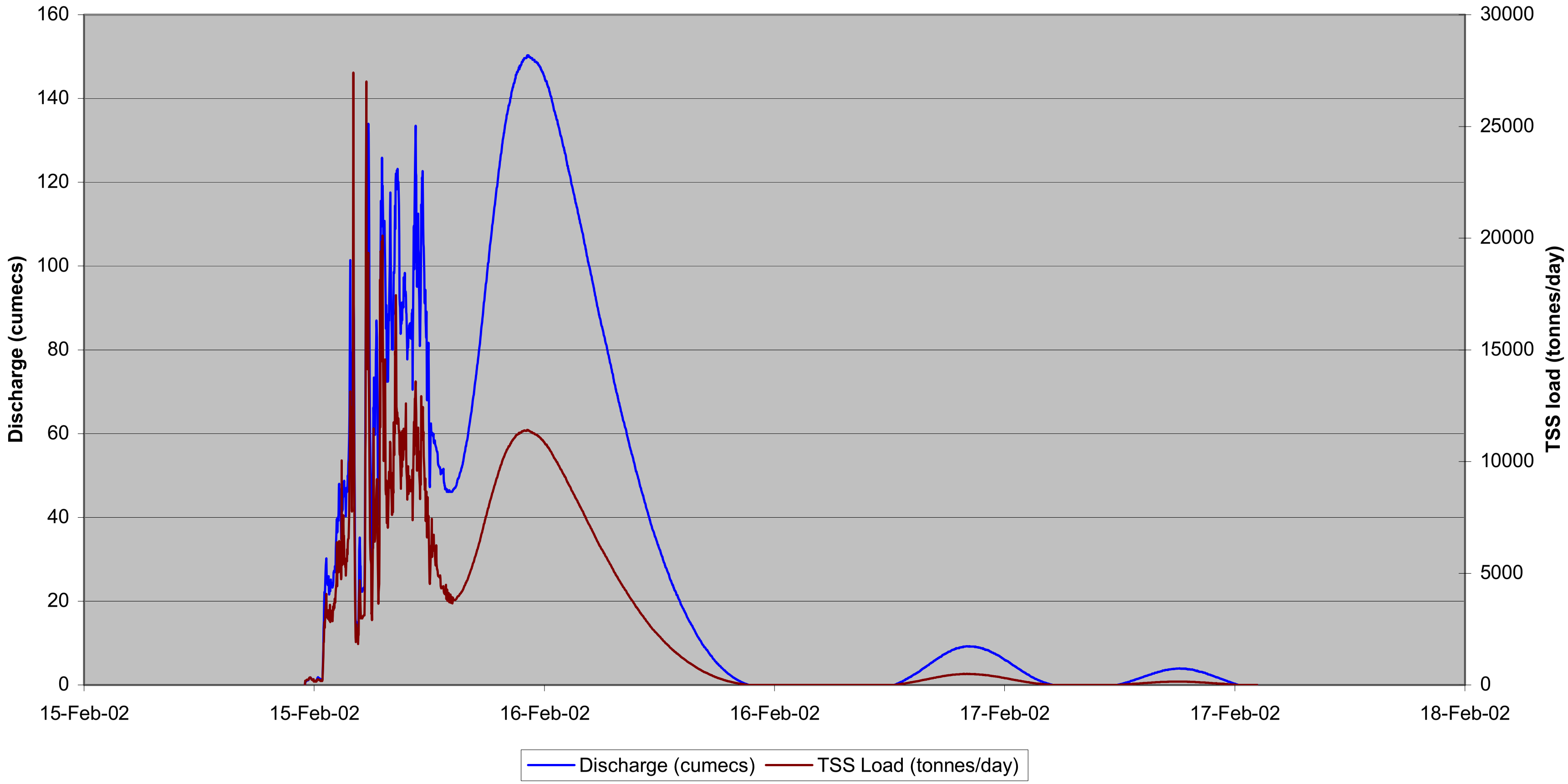

Wheel Creek 2000/2001
Discharge (cumecs)
25
20
15
10
5
0
TSS load (tonnes/day)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
04-Mar-01 12:00
04-Mar-01 13:12
04-Mar-01 14:24
04-Mar-01 15:36
04-Mar-01 16:48
04-Mar-01 18:00
04-Mar-01 19:12
04-Mar-01 20:24
04-Mar-01 21:36
04-Mar-01 22:48
05-Mar-01 00:00
Discharge (cumecs)
TSS load (tonnes/day)

Wheel Creek 2001/2002




Burdekin @ Macrossan 2001/2002
Discharge (cumecs)
TSS load (tonnes/day)
14000
12000
10000
8000
6000
4000
2000
0
1200000
1000000
800000
600000
400000
200000
0
13-Feb-02
15-Feb-02
17-Feb-02
19-Feb-02
21-Feb-02
23-Feb-02
25-Feb-02
27-Feb-02
Discharge (cumecs)
TSS load (tonnes/day)

Station Creek 2001/2002



Appendix 5. Grazing distribution study methods

Jeff Corfield[1], John Gross[1], Brett Abbott[1] and Taoufik Ksiksi[2]
[1]CSIRO Sustainable Ecosystems, Townsville
[2]Qld. Dept. of Primary Industries, Charters Towers

Overview

Studies in this project component consisted of vegetation measurements at three primary scales, and aerial surveys to document the distribution of cattle in the focal paddocks. Vegetation measurements at the two largest scales employed transects, while we used digital photographs to determine small scale pattern. In this Appendix, we provide detailed descriptions of the study paddocks and the methods used to collect data. Appendix 6 contains metadata for this component, and it includes descriptions of each variable, values for coded variable values, and notes on software used to analyze data.

In addition to data collected specifically for this study, we also used data from Fletcherview Paddock that was previously acquired, and we used a trend analysis conducted under the supervision of Bob Karfs. This Appendix also documents this information as appropriate.

Study paddocks

Three study paddocks – Virginia Park, Fanning River, and Fletchervale - were selected for cattle grazing and vegetation monitoring in December 1999 and January 2000.

Virginia Park – stud paddock (240 ha)

Location: 40k NE of Charters Towers, QLD, adjacent to Flinders Highway

Latitude 19 54' 00" Longitude 146 30' 36"

Soils/land system: Largely granodiorite soils of the moderately fertile Goldfields association, on gently undulating landscapes, with small alluvial components on lower slopes and flats associated with Weany Creek. Some exposed granite and stony areas associated with steeper gullies. Significant loss of A horizon on upper to mid slopes and active gully head erosion in places. Some extensive scalds associated with sodic soils on lower slopes.

Vegetation: Overstory vegetation dominated by Ironbark / Bloodwood (*E. crebra / C. erythrophloia*) and some ghost gum *(Corymbia dallachiana*) and few mid story shrubs on slopes, with areas of box (*E.Brownii*) and associated mid story shrubs (*Carissa, Erimophola, Atalaya, Cryptostegia*) on lower slopes and along major gully lines. Alluvial flats have an overstory of *E. Platyphylla* and some *E.teriticornis,* with *Allocasuarina sp* and some broad leaf species along creek lines. Riparian zones have significant infestations of rubber vine (*Cryptostegia).*

Understory herbage vegetation, once dominated by native perennial tussock grasses *(Heteropogon contortus, Bothriochloa ewartiana, Dicanthium sericeum, Chrysopogon fallax*), now largely replaced by Indian couch (*Bothriochloa pertusa*) in southern half of paddock especially. Some areas of tussock perennials remain in the north-west sector of the paddock.

Land condition and grazing management: Moderate to heavy stocking over many years, exacerbated by prolonged drought during the mid 1990s has degraded overall paddock to state II and state III land condition (Andrew et al, 2001). The paddock has been stocked at around 4-5ha / beast for most of the study period, though there have been several periods of de-stocking, mainly in the late wet/early dry, during this time. Early wet season grazing, following a late dry season burn in the southern half of the paddock in 1999/2000, concentrated grazing in this area for the following season. Early wet season grazing in 2000/2001 further weakened this area. Current annual dry matter production from this paddock is between 800-1200 kg/ha.

Fanning River - Mt Success paddock (2883ha)

Location: 27 north of Mingela on the Fanning River/Dotswood road adjacent to Mt Success.

Latitude 19 45' 36" Longitude 146 30' 00"

Soils/land system: Largely granodiorite soils of the moderately fertile Goldfields association, on gently undulating landscapes, with smaller areas of sandy alluvial soils on lower slopes and flats, associated with major creek and gully systems, which feed into the Fanning River catchment. Some exposed granite and stony areas associated with steeper gullies and some steep rocky hillslopes and ridges in the northern half. A major rocky limestone ridge system also marks the northern boundary, whilst Mt Success marks most of the western boundary. Significant gully systems occur throughout the paddock, with some scald areas associated with sodic soils also present on lower slopes adjacent to gully systems.

Vegetation: Overstory vegetation dominated by Ironbark / Bloodwood (*E. crebra / C. erythrophloia*) and some ghost gum (*Corymbia dallachiana)* with few mid story shrubs on slopes. Small areas of box (*E.Brownii*) and associated mid story shrubs (*Carissa, Erimophola, Atalaya, Cryptostegia)* on lower slopes and along major gully lines. Sandy alluvial flats between creek lines also have significant mixed shrub cover, dominated by *Carissa, Atalaya, Bursaria Erythroxylum, Planchonia and Petalostigma* species. Some areas of heavy alluvials have an overstory of *E. Platyphylla* and some *E.tericornis* with *Allocasuarina, Melaleuca bracteatus, Lophostemon along* creek lines. Riparian zones have significant infestations of rubber vine (*Cryptostegia) in places.*

The Limestone ridge area is dominated by broadleaf, often semi-deciduous dry rainforest/ vine scrub upper and mid story species such as *Brachychiton, Lysophyllum, Terminalia, Owenia, Cocholospermum, Sterculia*, with an understory of vines such as *Canavalia* and other legume species. Steep rocky hillslopes and ridges also carry some a mixture of broadleaf tree and shrub species alongside ironbark and mixed bloodwood associations.

Understory herbage vegetation for the granodiorite areas is a mixture of native perennial tussock grasses *(Heteropogon contortus, Bothriochloa ewartiana, Dicanthium sericeum, Chrysopogon fallax*), with significant areas of Indian couch (*Bothriochloa pertusa*) in southern half of paddock especially, where the A horizon has been lost from mid and upper slopes and ridges.

Land condition and grazing management: The paddock is in a recovery phase from the impacts of past heavy stocking and prolonged drought. Extensive gully systems and sheet erosion in places, confirms its previously degraded state. The paddock has been moderately stocked at around 8-9ha / beast and is currently in an advanced state II land condition with some areas in state I (Ash et al, 2001). Though Indian Couch dominates significant areas, much of the paddock has good 3P perennial tussock grass cover, though tussock grass basal area is still <2% overall. Whilst some grazing is concentrated along ridges, the presence of six water points distributed around the paddock serves to spread grazing. Use of early wet season mosaic burning has also helped to shift the grazing distribution within the paddock. Mean paddock annual dry matter production is around 1500-1800 kg/ha

Fletchervale - Allingham Creek paddock (2500ha)

Location: 60km north of Charters Towers on the Lynd Highway

Latitude 19 53' 24" Longitude 146 12' 00"

Soil type/land system: The paddock is comprised of fertile basaltic red ferrosol soils and associated basaltic vertisols (heavy grey-brown cracking claysoils) and basalt sediments and colluvial soils typical of the "basalt country" to the north west of Charters Towers. The paddock includes red basalt plateaux areas to the west – part of a more recent basalt flow, which ends in a rocky "jump-up" areas just west of Allingham Creek, which divides the paddock longitudinally. There are extensive claysoil flats either side of the Allingham Creek, intersected by small anabranches and billabongs, which form part of an extensive channel system associated with the creek. Extensive areas of basalt sediments (a mosaic of rock free brown loams and cracking clay depressions) adjoin the claysoil flats to the east of Allingham Creek. The areas occur in several longitudinal bands, separated by low rocky basalt outcrops or ridges and adjoining stony colluvial margins and areas rocky red basalt plains.

Vegetation: The red basalt plateaux and plains are dominated by narrow leaf ironbark/bloodwood (*E. crebra / C. erythrophloia)* overstory, with few mid story shrubs. The rocky basalt ridges and slopes carry a significant mid-story shrub complex of *Carissa, Atalaya, Erythroxylum, Flindersia* . Claysoil flats are dominated by a box/coolibah overstory, whilst basalt sediments carry a mixed eucalypt overstory of silver leaf ironbark, (*E. Melanophloia*) ghost gum (*C.dalachiana*), box (*E. Brownii*) and bloodwood (*E. erythrophloia).* Basalt margins are dominated by a shrubby mid-story of false sandalwood (Eromophola mitchellii), Carissa and *Flindersia.* The riparian zone along Allingham Creek supports an overstory of *E. coolibah*, *Allocasuarina* sp. and *Melaleuca bracteata.* At the southern end of the paddock, Allingham Creek runs into Alligham Swamp, and extensive ephemeral wet land area, which is partly infested by *Parkinsonia* and restricts cattle access.

The herbaceous understory of the red basalts is dominated by 3P tussock grasses such as *Bothriochloa ewartiana, Heteropogon contortus* and *Dicanthium sericeum*, with significant invasion of buffel grass (*Cenchrus ciliaris*) and sarbi grass (*Urochloa mosambicensis),* along with an array of legume and non-legume forb species. Basalt ridges and outcrops are characterized by the presence of giant spear grass (*Heteropogon triticeus*). Cracking claysoil flats are dominated by perennial tussock grasses such as *Dicanthium sericeum, Dicanthium aristatum, Panicum decompositum* and *Eriochloa* spp. Basalt sediments support the range of both red soil and black soil species listed above. Stony colluvial margins have support a limited grassy under-story dominated by *Sporobolus, Eragrostis*, and other annual or short lived perennial species.

Land condition and grazing management: The paddock has been lightly stocked over many years and despite the impact of prolonged drought during the 1990s remains in good (state I) condition overall. A program of mosaic early wet and late wet season burning shifts grazing pressure around the paddock. Unlimited access to the perennial Allingham Creek limits potential grazing gradient impacts. Even so, most grazing tends to occur on the basalt plateau adjacent to a mill and also over the basalt sediment areas on the north-eastern side of the paddock. Production is about 1500-2000 kg/ha.

Fletcherview - Sandalwood paddock (467ha)

Location: Approximately 30k north of Charters Towers on Lynd Highway

Latitude: 19° 53' 24" Longitude 146° 12' 0"

Soil type/land system: The paddock is comprised of fertile basaltic rocky red ferrosol soils and associated basaltic vertisols (heavy grey-brown cracking claysoils) and basalt sediments and colluvial soils typical of the “basalt country” to the north west of Charters Towers. There are also small areas of exposed underlying granodiorite and sedimentary soils and sandy alluvial flats associated with Hann Creek, which marks the southern boundary of the paddock. The paddock includes several low basalt ridges and “walls” associated with a more recent basalt flows, which terminated at the border of Hann Creek. There are extensive claysoil flats on the northern side of the paddock adjacent to Lynd Highway separated from the red basalt soils by stony colluvial “margins” – a mosaic of brown basalt sediments and grey claysoil depressions and gilgais. Extensive areas of basalt sediments - a mosaic of rock free brown loams and cracking clay depressions) adjoin the western boundary. Significant areas of sheet, rill and gully erosion occur adjacent to Hann Creek, within both alluvial soils and adjacent sedimentary and granite derived soils.

Vegetation: The red basalt plateaux and plains are dominated by narrow leaf ironbark/bloodwood (*E. crebra / C. erythrophloia)* overstory, with few mid story shrubs. The rocky basalt ridges and slopes carry a significant mid-story shrub complex of *Carissa, Atalaya, Erythroxylum, Flindersia* . Claysoil flats are generally treeless or carry a scatttered box overstory, whilst basalt sediments carry a mixed eucalypt overstory of silver leaf ironbark, (*E. Melanophloia*) ghost gum (*C. dalachiana*), box (*E. Brownii*) and bloodwood (*E. erythrophloia).* Basalt margins are dominated by a shrubby mid-story of false sandalwood (*Eremophola mitchellii*), *Carissa* and *Flindersia.* The Hann Creek riparian zone supports an overstory dominated by *Melaleuca leucodendron*, *Eucalyptus tesserlaris*, *Allocasuarina* sp. Rubbervine (*Cryptostegia*) is a significant weed of both the riparian and gully areas, colluvial margins and basalt ridges.

The herbaceous understory of the red basalt areas is dominated by perennial tussock grasses such as *Bothriochloa ewartiana, Heteropogon. Contortus* and *Dicanthium sericeum*, with significant amounts of buffel grass (*Cenchrus ciliaris*) and sarbi grass (*Urochloa mosambicensis),* along with an array of legume and non-legume forb species. Basalt ridges and outcrops are characterized by the presence of giant spear grass (*Heteropogon triticeus*) and red natal grass (*Melenis repens*). Cracking claysoil flats carry perennial tussock grasses such as *Dicanthium sericeum , Panicum decompositum* and *Eriochloa* spp., with some bull mitchell (*Astrebla squarrosa*) and an array of legume and non-legume forbs. Where prolonged heavy grazing has reduced the perennial grass component, these flats are dominated by annual grasses such as *Brachyanche convergens* and *Sporololus spp*. Basalt sediments and colluvial margins support the range of both red soil and black soil species listed above, with the more scalded/shrubby areas carrying a limited grassy understory dominated by *Sporobolus, Eragrostis*, and other annual or short lived perennial species.

Land condition and grazing management: The paddock has been moderately stocked over many years and despite the impact of prolonged drought during the 1990s remains in generally good condition. Despite this, several areas of the paddock have been preferentially grazed over sustained periods resulting in localized degradation, scalding and significant erosion, especially along the Hann Creek frontage. The cracking claysoil plains fronting Lynd Highway have also suffered preferential prolonged grazing, especially through the 1990s drought, which significantly altered the pasture composition from tussock perennial to annual in character. Overall paddock dry matter production was around 1300 kg/ha throughout the mid-1990s drought, when this paddock was under study.

The paddock at Meadow Vale that was used for sub-catchment studies in this project was not included in the grazing / vegetation studies because of its small size, uniform vegetation, and uniformly heavy grazing regime. For selected paddocks, a GPS-based survey was conducted to record paddock boundaries, water points, major veg and soil types were completed in January/February 2000. This information formed the basis for paddock GIS maps, which were later refined using information from subsequent veg surveys.

Full-paddock vegetation measurements – methodology

Vegetation sampling using transects was based roughly on BOTANAL protocols (Tothill et al, 1978). However, to evaluate spatial pattern it was necessary to devise a protocol that could be used over large areas, such at entire paddocks, and that would detect patterns that resulted from grazing, which might be at scales or 10s to 100s of meters. To sample full paddocks, we evaluated two basic protocols. The first, used for sampling in June and July 2000, was based on the concept of sampling "active" and "inactive" sites, as determined from aerial sampling of cattle. Our initial vegetation sampling (June/July 2000) used four-armed, non-aligned transects placed at locations where we observed cattle ("active" sites) and at locations where no cattle were observed ("inactive" sites). The sampling technique yielded high-resolution data at sampled sites, but it was too labour-intensive to sample the full range of spatial locations and vegetation zones in large paddocks. In particular, it took a long time to travel to and locate each specific site using a hand-held GPS, and a considerable effort was necessary to lay out the transect tapes for the four-arm sampling protocol. We therefore evaluated alternative sampling schemes, and adopted the use of linear non-aligned transects. Vegetation sampling relied on linear transects, typically 1-2 km long, with quadrats placed at random locations within each 20 m segment of the entire transect. Using this technique, we were able to measure spatial patterns in the vegetation (see below) and the technique proved to be highly efficient.

Initial full paddock vegetation sampling methodology

Following initial aerial cattle distribution surveys of all three paddocks in May-June 2000, the following Botanal-based vegetation sampling methodology was used.

1. A set of pre-determined sampling points representing "active" (grazed) and "inactive" (ungrazed) areas across the paddock were selected, using data from recent aerial cattle distribution surveys. The aim was to cover both grazed and un-grazed areas across the range of major vegetation communities, soil types and significant landscape features in each paddock, within the time and resources available.

At each of these GPS located sampling points, observers, working in pairs, scored eight 2m*2m virtual quadrats at positions located in a stratified random manner, along each of four * 100m transect arms radiating out in cardinal directions from the central point. For Virginia Park, the direction of each was: 1: up-slope from site centre, 2: cross-slope to right of centre, 3: down-slope from centre, 4: cross-slope to left of centre. For the other paddocks, the arms were (in order of 1-4) north, east, south, and west.

2. 2m*2m quadrat positions were located at a random point within each 15m stratum (measured from the centre; Figure 5.1) along each transect arm, allocated on a stratified random basis as follows.

Quadrat	Distance Stratum	Actual Distance
1	0 (site centre)	always 0 m
2	0-15m	random within category (1m intervals)
3	16-30m	random within category (1m intervals)
4	31-45m	random within category (1m intervals)
5	46-60m	random within category (1m intervals)
6	61-75m	random within category (1m intervals)
7	76-90m	random within category (1m intervals)
8	91-105m	random within category (1m intervals)

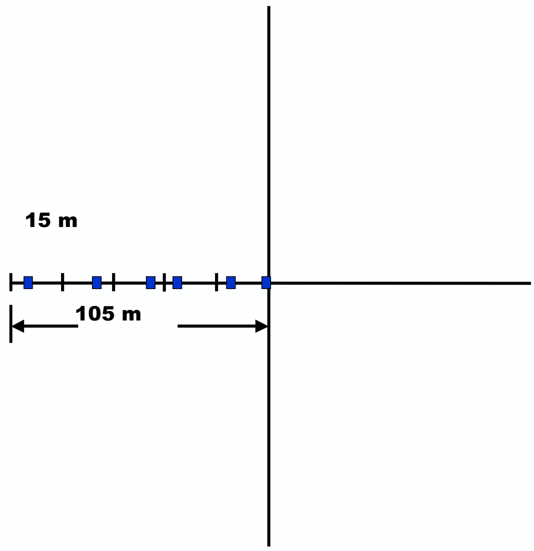


Figure 5.1: Quadrat placement design for sampling in April 2000.

Quadrat numbering was always 1-8 from centre to last quadrat along each arm. Quadrat 1 (site centre) was scored at least once by each observer (for comparison purposes), but where sites were scored by teams of 2 observers (scoring 2 arms each), quadrat 1 was not scored the second time around.

3. GPS locations at the start and end of each arm were recorded to enable accurate recording of quadrat positions on paddock GIS. 100m tapes were used to accurately locate the transect lines and quadrat positions for scoring.

Non-aligned transects methodology

An important observation from our July 2000 sampling was the large amount of time it took to locate, set up, and complete sampling at each site. We therefore modified the protocol for the November 2000 sampling and onwards to increase efficiency of sampling. From this sampling on we began using linear non-aligned transects that intersected actively grazed and un-grazed areas of each paddock. The location, direction and length of these transects was determined from paddock vegetation maps derived from aerial photography (Virginia Park), satellite imagery and accumulated paddock GIS data. Again, the aim was to intersect as many grazed and un-grazed areas as possible, across the range of major vegetation communities, soil types and landscape features in each paddock, within the time and resources available.

Sampling design for non-aligned transects

The non-aligned transects methodologies was used for all subsequent samplings. Each transect was divided into 200m (240 pace) sections (or parts thereof, where transects met fence lines or finished at the intersection with other transects). Within each 200m section, ten (10) quadrat positions were allocated to pre-determined random positions stratified between ten 20m (24 pace) sub-sections. Thus no quadrat could be more than 40m from its neighbour, but could be as close as 1m.

Pre-determined transect start and end positions and directions were located and followed using “go-to” and “routes” GPS functions. Observers mostly worked in pairs, “leap-frogging’ each other as they scored alternate 200m sections. Distances to quadrat positions were paced out – not measured by tape as previously. GPS locations were recorded at the START (0 paces) and END (240 paces) positions of each section, so that paced quadrat distances could be normalized. Where transects intersected fences, impassable waters etc. the last full quadrat position was scored and the remaining distance to the obstruction recorded as the END distance and GPS position, in place of the next quadrat distance listed on the HP spreadsheet program. Details of sampling instructions sheets can be found in Appendix 6 of this document.

The following variables were scored during the course of this study, with some variables being adapted or replaced and others added as sampling methodology evolved.

Variables recorded for each quadrat – all sampling periods

PAD:	Paddock (VPark=Virginia Park, FVale=Fletchervale, FRiv=Fanning River)
DATE:	ddmmyy
SITE:	1-N
OBS:	Observer initials: (JC, PA,PF,TK)
TOPO:	Local Topography (1-7)
BURN:	1=unburnt, 2=burnt
SP1-SP3:	3 dominant pasture species (as spec. nos. in Botanal biomass rank order)
YIELD:	Yield estimate - Botanal comparative yield estimate (0-100)
DEF:	Defoliation rating (O-5) 0=nil, 1=<5%, 2=5-25%, 3=25-50%,4=50-75%, 5=>75%)
COV:	Total projected cover estimate (0-100) – calibrated estimates
BAS:	Perennial tussock grass basal area category (0=nil, 1=<1%, 2=1-2.5%, 3=>2.5%
GRN_PC:	Green % of pasture (0-100%) – calibrated estimates
ER_TYPE:	Dominant soil surface erosion (0-3) 0=none, 1=sheet, 2=rill, 3=gully – visual assessment
ER_SEV:	Severity of erosion (0-3) 0=nil, 1=some, 2=moderate, 3=severe - visual assessment
COMMENTS	Any comments about the quadrat or site for future reference

Variables scored for June/July 2000 sampling only

ARM: Sampling Arm no. (1-4) in clockwise direction

DIR: Arm direction (NESW)

QUAD: Quadrat no. (1-8 from 0-105m along transect)

VEGCOM: Dominant vegetation community/land type within 10m radius (1-8) –see Appendix 6

Variables added or substituted from November 2000 onward sampling

T_SECT: Main transect number

SECTION: Sampling section number along each transect (1-n)

WAY_PT: GPS waypoint number (recorded at START or END of section)

QUAD: Quadrat no. (1-10 from 0m-200m along SECTION)

TOPO: Local topgraphy (1=flat, 2=ridge, 3=mid-slope, 4=downslope, 5=gully, 6=swale, 7=creek)

VEGCOM: Vegetation community (1-5) – consolidated paddock lists, see Appendix 6

Variables added or modified -- April 2001 onwards

VEG Dominant vegetation community within10m radius (code 1-8) see list Appendix 6

When initially established for the November 2000 sampling, the three study paddocks had the following number of non-aligned transects.

Table 5.1: Overview of transect sampling intensity

Paddock	Number of Transects	Total Length	Total Quadrats
Virginia Park	13	~12k	~ 598
Fanning River	15	~19k	~ 794
Fletchervale	14	~20k	~1018

At subsequent samplings in April 2001 and October 2001 additional transects were added at Fanning River (transects 16,17,18). These increased total transect length by 6k to 25k and total quadrats by 300 to approx. 1100. At Virginia Park there was also some re-alignment of transects from April 2001, which altered total length and number of quads slightly, whilst at Fletchervale, the total transect length and number of quads varied seasonally, according to the impact of Allingham swamp on transects 7 and 8. On some sampling occasions certain transects were not scored due to time constraints, whilst on other occasions some transect data was lost due to equipment problems (details in Appendix 6 of this document).

Data collection varied slightly between paddocks in June/July 2000, as the field sampling techniques were refined during the sampling exercise. Such variations were as follows:

1. At Virginia Park there was initially no discrete TOPO field recorded, but comments on topography were recorded.
2. At Virginia Park an additional field recording whether site/quadrat was previously burnt was included here. This variable was subsequently added to all study paddock data sets from November 2000 on.

3. At Virginia park perennial tussock grass basal area was recorded as a direct % estimate, but this was changed on subsequent paddocks to a rating, due to difficulty in obtaining accurate direct % estimates in thick pasture.
4. At Virginia Park, arms were not located north, east, south and west but up-slope, cross-slope (right), cross-slope (left) and down-slope). On other sites they were located N, E, S, W.

Reference quadrat establishment and observer training

Immediately prior to the initial paddock vegetation surveys in July 2000, sets of 4 m^2 permanent reference quadrats, covering a range of biomass, cover, species composition and defoliation combinations were established at strategic locations in all three study paddocks, for the purpose of on-going observer training and standardization and as photo points for on-going reference. At Virginia Park and Fanning River a total of 11 such reference quadrats were established, while 13 were established at Fletchervale. These quadrats were used both for initial training in scaling between 1 m^2 and 4 m^2 quadrats and also for on-going training, standardization and calibration at every subsequent sampling. Photos of all reference quadrats were taken by Taoufik KsiKsi, or Jeff Corfield, at each sampling and are held by Jeff Corfield. Details of reference quadrat training and calibration methods can be found in Appendix 6.

Hillslope-scale patchiness measurements - methodology

Whilst non-aligned Botanal based transects provided good data on the broad spatial relationships between observed grazing patterns and factors such as vegetation type, soil type, distance from water, fences etc. little information was gained on the actual size or dynamics of grazed patches across the paddock. Understanding patch dynamics may be a key to linking broader scale grazing impacts with plant/soil/hydrological processes and landscape function. Thus, in July 2001, a series of “intermediate scale” (100m) transects was established along sections of selected non-aligned transect lines in Mt Success study paddock, Fanning River Station, to record temporal changes in the dynamics of grazed and ungrazed patches at sub-10m scales.

Initial patch transect establishment

Patch transects were initially established along three 100m sections of transects 12 and 15 in Mt Success study paddock, to intersect a range of cover, species composition and grazing patterns, in particular, sections that included distinct bare (scald) patches, creek/gully lines, light, moderate and heavily grazed patches (see Appendix 6 for descriptions and locations). Patch transect start points were located by trees flagged with coloured surveyor’s tape, or wooden pegs, whilst end points were usually marked by wooden pegs. GPS waypoint positions were recorded at the start and end points of each 100m transect section. The initial 6 patch transect sections (3 along Transect 12 and 3 along transect 15) were not contiguous. 100m survey tapes were used to mark out patch transect lines and patch information was scored within a 1m belt transect located centrally along the tape.

Initial patch measurements, variable descriptors and definitions – July 2001 scoring

A number of “patch types” were identified and recorded along each 100m tapeline. A full list and description of patch codes used at all scoring occasions appears in Appendix 6 of this document. Main patch types included bare ground, grazed patches, un-grazed patches, intermittent grazed and ungrazed patches, cattle pads and camps, creek and gully banks and beds. Scoring was continuous along tape-lines, with every portion of each 100m transect assigned a “patch” category. Linear boundaries of each “patch” were recorded in an HP 200 spreadsheet, along with date of scoring, transect, section and scores for the following list of variables.

Changes to recording methodology at second scoring – September 2001

At the second scoring occasion, the following changes were made to variables recorded and recording methodology.

1. Standing crop herbage biomass (Botanal comparative yield method, Tothill et al 1978)) was added

2. Bare and grazed patch maximum and minimum diameters were abandoned
3. Dominant species variables increased from first two to first three
4. Herbage defoliation rating (Andrew 1988) was added
5. Estimation of all variables was confined to a 1m wide belt transect along tape centre line
6. Additional patch types were also recorded (see consolidated list below)

The following variables were scored during the course of this study, with some variables replaced or modified and others added as the sampling methodology evolved.

Variables scored for each transect - all sampling occasions

SITE	Catchment study paddock FRIV = Fanning River (Mt Success Paddock)
DATE	Sampling Date (DD-month-YY)
TRANSECT	Paddock veg survey Botanal transect number (1-19)
SECTION	100 m section of transect bounded by start and end waypoints
WAY_PT	GPS way point number marking beginning or end of section
PATCH	Patch Type - see separate code and description list
DISTANCE	Distance (in meters and decimeters) from start of 100m section to point measured
COVER	Mean total projected cover estimate for patch (%)
PAST_HT	Mean pasture height (cm) for patch - to flag leaf , excluding inflorescences
DOM_SP1	First dominant species (Botanal DWR method)
SP1_PERC	Estimated % contribution of first dominant species (%)
DOM_SP2	Second dominant species (Botanal DWR method)
SP2_PERC	Estimated % contribution of second dominant species (%)

Variables scored July 2001 only

MAX_DIAM	Diameter of longest axis of significant bare or grazed patch (cm)
MIN_DIAM	Diameter of shortest perpendicular axis of significant bare or grazed patch (cm)

New variables added September 2001 onward

DOM_SP3	Third most dominant species or species group in patch (Botanal DWR method)
SP3_PERC	Estimated percentage biomass of dom_sp3
YIELD_EST	Standing Crop Biomass (Botanal comparative yield estimate) -scale 0-100
DEFOL	Mean defoliation rating for patch on a 0-5 scale (Andrew 1986)
BURN	1=unburnt, 2=recently burnt

Detailed descriptions of variables and patch types can be found in Appendix 6 of this document.

Small scale patch measurements - methodology

Digital imagery was used to capture small scale measurement of patch attributes along existing sections of the hillslope patch transects, both for comparison with intermediate scale observations and to better understand patch and sub-patch dynamics.

We used a digital camera (5 mega-pixel) attached to a boom affixed to a quad bike, which yielded images of a 4.6m x 3.5m area. Imagery was classified into green foliage, cover and bare ground elements using standard image processing methodology. Patterns of bare ground were described quantitatively using statistical distributions and landscape metrics to derive connectance, lacunarity percolation and "landscape leakiness" – all of which are indicators of landscape hydrological function. Patterns of cover at the small-scale were related to vegetation type, soil characteristics, defoliation and topography.

Table 5.2: Variables and attributes measured

Variable	Method / definition	Reference	Unit
Classification	Supervised maximum likelihood		
Green foliage	Foliage greenness		% of image
Cover	Any grass (including green foliage) or litter element.		% of image
Bare ground	Bare earth not covered by a grass or litter element		% of image
Statistical distributions			
Mean, variance etc	Computed from the number of patches (soil and cover) and patch sizes		
Landscape analysis			
Leakiness	Measure of leakiness of a landscape unit	Ludwig et al (2001)	Directional leakiness index (DLI)
Patch metrics	Various descriptive metrics used to describe landscapes. Lacunarity, percolation and connectance are a few examples.	APACK and FRAGSTATS software packages	Descriptive indexes

See Appendix 6 of this document for detailed descriptions of variables and data obtained.

Aerial surveys for determining cattle distribution

Cattle distributions were documented in the three focal paddocks (Virginia Park, Fanning River, and Fletchervale) by conducting low altitude aerial surveys of paddocks at Virginia Park, Fanning River, and Fletchervale. Cattle locations were determined by flying low-elevation (approximate 150 m above ground) linear transects approximately 400 m wide and to record the size and location of each mob observed. For each mob of cattle, the location was recorded as a GPS waypoint, and the number of animals in the mob was recorded. As necessary, the aircraft circled area to ensure that all animals were observed or to provide a longer period to count large mobs. Locations were determined from GPS data and notes made at the time of observation. After transects were completed, locations were refined by comparing notes and GPS locations to aerial photographs and/or TM images. To emphasize spatial distributions while animals were feeding, morning flights began as soon as light permitted; evening flights were scheduled to occur during period when animals were active. Because of the long distance between some paddocks, surveys of Virginia Park and Fanning River were generally conducted during the same flight, and Fletchervale was surveyed as a separate flight. Flights were scheduled for the period of about 1 month before vegetation sampling to facilitate comparison of aerial locations to vegetation attributes.

Appendix 6. Grazing distribution studies metadata

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Overview

The purpose of this appendix is to provide a compilation of the metadata of all of the measurements conducted in the grazing distribution component of NAP3.224. The metadata information has been organised into a series of tables listing variables captured and their description.

Paddock scale vegetation sampling - main metadata

Table 6.1: Descriptions of all variables recorded in paddock-scale vegetation sampling, 2000-2002

Variable	Description / Definition	Reference	Units or categories
PAD	Paddock ID – 4 letter code	NA	VPARK=Virginia Park, FVALE=Fletchervale, FRIV=Fanning River
DATE	Sampling date	NA	dd-Mon-yy
OBS	Observer code	NA	JC=Jeff Corfield PA=Peter Allen TK=Taoufik KsiKsi PF=Peter Fry LW=Lindsay Whiteman CH=Chris Holloway BA=Brett Abbott
ARM	Sampling arm number. There were four*100m long sampling arms arrange at right angles to each other at each sampling site. Applicable for July 2000 sampling only	NA	1-4 for all sites For Virginia Park only 1=upslope 2=downslope 3=cross-slope left of centre 4=cross-slope right of centre
DIR	Direction of each sampling arm. Applicable for July 2000 sampling only at Fletchervale and Fanning River	NA	N=north of centre S=south of centre E=east of centre W=west of centre
TREAT	Category of selected sampling site (actively grazed or ungrazed) - used for July 200 sampling design only	NA	Categorical variable 1=selected active (grazed) site 2=selective inactive (ungrazed) site
T_SECT	Transect number (used from Nov. 2000)	NA	1-n
SECT	200m Section number (used from Nov. 2000)	NA	1-n
WAY_PT	GPS waypoint number each ARM centre and end (July 2000) or for start and end of each section (from Nov 2000)	NA	1-n – corresponds with GPS waypoint recorded as UTMs in GWS84

QUAD	$4m^2$ quadrat number	NA	1-10
PACES	Number of paces from START of section or previous quadrat to next quadrat or END of section	NA	0-40 paces. Start position recorded as START or "0"; end point recorded as END or "999"
VEG or VEGCOM	Code number recorded for dominant veg community or landtype within a 10m radius of quadrat – see separated detailed descriptions below	NA	1-n - number of categories varied with sampling date as methods evolved
TOPO or SOIL_TOPO	Code number recorded for dominant topographical feature and / or soil type within a 10m radius of quadrat – see detailed descriptions below	NA	1-n - number of categories varied with sampling date as methods evolved
BURN	Status of quadrat in relation to recent burning	NA	1=unburnt 2=burnt
SP1	Code number for most dominant herbage layer species or group – Botanal comparative yield estimate method	BOTANAL Tothill et al (1978)	Species ID number 1-26 See separate ID list in this document
SP2	Code number for second most dominant herbage layer species or group - Botanal comparative yield estimate method	BOTANAL Tothill et al (1978)	Species ID number 1-26 See separate ID list in this document
SP3	Code number for third most dominant herbage layer species or group - Botanal comparative yield estimate method	BOTANAL Tothill et al (1978	Species ID number 1-26 See separate ID list in this document
YIELD	Calibrated estimate of total standing dry biomass of herbage present in quadrat – Botanal comparative yield estimate method	BOTANAL Tothill et al (1978)	Rating scale of 0-100, converted to kg/ha dry matter using regressions derived from calibration standards
COV	Calibrated estimate of total projected cover (folia + litter + rocks) of quadrat		0-100% - data adjusted by regressions derived from calibration standards
DEF	Visual rating of defoliation within quadrat, using an un-calibrated 0-5 rating scale	Andrew (1986)	Categorical variable 0-5 scale 0=nil, 1=<5% 2=5-25% 3=25-50% 4=50-75% 5=>75% - converted to mid-point percentage
BAS	Perennial tussock grass basal area category. Note B. pertusa BA not included in this as not a tussock grass	Tongway (1995)	Categorical variable 0-3 scale 0=nil, 1=<1% ba 2=1-2.5%, 3=>2.5%
GRN_PC	Calibrated Estimate of percentage of standing biomass which is green at each sampling		0-100% in units of 1%

ER_TYPE	Dominant erosion category for each quadrat, loosely based on Tongway LFA system	Tongway (1995)	Categorical variable 0=no erosion 1=sheet erosion 2=rill erosion 3=gully erosion
ER_SEV	Erosion severity category for each erosion type – loosely based on Tonway LFA system	Tongway (1995)	Categorical variable 0=no erosion 1=slight 2=moderate 3=severe
COMMENTS	Any comments specifically related to quadrat, section or transect, recorded at time of scoring each quadrat		Text

Table 6.2: Consolidated species shortlist for transect Botanal data 2000-2002

BOTNUM	SPECIES	Functional group 1	Functional group 2	Functional group 3
1	*Aristida* spp.	perennial grass	native	increaser
2	*Bothriochloa decipiens*	perennial grass	native	decreaser
3	*Bothriochloa ewartiana*	perennial grass	native	increaser
4	*Chrysopogon fallax*	perennial grass	native	intermediate
5	*Dichanthium spp.*	perennial grass	native	decreaser
6	*Enneapogon sp*	perennial grass	native	increaser
7	*Heterogon contortus*	perennial grass	native	decreaser
8	*Heteropogon triticeus*	perennial grass	native	decreaser
9	*Themeda triandra*	perennial grass	native	decreaser
10	*Sorghum plumosum*	perennial grass	native	decreaser
11	Other native per. grasses	perennial grass	native	intermediate
12	*Bothriochloa pertusa*	perennial grass	exotic	increaser
13	*Melenis repens*	perennial grass	exotic	increaser
14	*Cenchrus ciliaris*	perennial grass	exotic	increaser
15	*Urochloa mosambicensis*	perennial grass	exotic	increaser
16	Other exotic grasses	perennial grass	exotic	increaser
17	*Dactylocteneum radulans*	annual grass	native	increaser
18	*Sporobolus* sp.	annual grass	native	increaser
19	*Tragus austalianus*	annual grass	native	increaser
20	Other annual grasses	annual grass	native	increaser
21	Legumes	legume	mixed	mixed
22	Sedges	sedge	native	mixed
23	Forbs	forb	mixed	mixed
24	*Panicum* spp.	perennial grass	native	decreaser
25	*Eulalia aurea*	perennial grass	native	intermediate
26	*Dichanthium aristatum*	perennial grass	native	increaser

Detailed descriptions of VEGCOM, VEG and TOPO codes used in paddock scale sampling

VEGCOM field indicated broad land type – a combination of vegetation community, soil type and landscape features broadly equivalent to the system of land types used in the Fletcherview study and comparable to land units. VECOM codes and identities used for each study paddock at the July 2000 sampling are listed in Table 6.3 below. Both VEGCOM and TOPO variables were recoded as the dominant feature within a 10m radius of the quadrat centre.

Table 6.3: VEGCOM codes - July 2000 sampling

VEGCOM	VIRGINIA PARK	FANNING RIVER	FLETCHERVALE
1	Ironbark/bloodwood	Ironbark/bloodwood	Ironbark/bloodwood
2	Gully systems	White Gum Flats	Basalt colluvium
3	Riparian	Sandalwood/ shrubby	Black Soil
4	Box/Carissa	Box Flats	Box flats
5	Sandalwood (*Eremophola*)	Riparian	Riparian
6	Stony Goldfields	Mixed Euc./rocky hills	Basalt ridges
7		Limestone ridge	
8		Gully systems	

Detailed VEGCOM code descriptions – July 2000 sampling

Virginia Park vegetation communities

1. Ironbark/bloodwood. *E. crebra/C. erythrophloia* over *B .ewartiana, H. contortus, C. fallax*, now dominated by B.pertusa. Undulating topography on Dalrymple neutral red duplex soils).

2. Gully Systems — Mixed Eucalypt and shrubs (*Atalaya, Carissa, Eromophola, Cryptostegia*) over annual and perennial grasses mostly dominated by *B. pertusa*. Associated bare scalds, rills and gullies.

3. Riparian – creeks — Major creek lines dominated by *E. tesserlaris, E. teriticornis, E. platyphylla* and *Melaleuca sp*. over mixed perennial grasses. Exotic grasses such as *B. pertusa* and *U. mosambicensis* dominate open areas whilst *Cryptostegia* and other exotic weeds occupy mid-story.

4. Box/Carissa — *E. brownii, Carissa sp., Cryptostegia* over *H. contortus, Aristida sp., Sprobolus sp.* on heavy clay loams in lower slopes adjacent to creeks. Associated scalds and bare patches and heavy rubber vine infestation in places.

5. Eremophola — Scattered *E. brownii* and *C. dallachiana* over E.*mitchellii/Atalaya/Carissa* mid story and *Sporoblus/Aristida/Enneapogon* understory. Significant bare scalds, sheeting, rills, gullies.

6. Stony Goldfields — *E. Crebra/C. erythrophloia/C. dallachiana* over *B. ewartiana, Enneapogon spp., H. contortus* on undulating topography with rocky/stony surface – goldfields neutral red duplex soils.

Fletchervale vegetation communities- July 2000

1. Red Basalt — *E. Crebra/C. erythrophloia/C. dallachiana* (Ironbark/bloodwood) over *B. ewartiana , D. sericeum, H. contortus* (with significant invasion of *Cenchrus and Urochloa* spp) on rocky red basalt soils in flat to undulating topography. Generally well covered with minor scalds.

2. Basalt colluvium — Mixed Eucalypt (*E. crebra, C. erythrophloia, E. melanophloia, C. dallachiana*) over *B. ewartiana, B. decipiens, D . sericeum , D. aristatum*. On flat to slightly undulating country, almost rock free, with associated blacksoil depressions and gilgais. Usually in margins between red basalt and box areas.

3. Black Soil — Scattered *E. brownii* over *D. sericeum/D. aristatum, P. decompositum* on heavy grey cracking clay soils in almost treeless, lower lying areas between red basalt areas and riparian zones.

4. Box flats	*E. brownii* over *D. sericeum, D. aristatum, B. decipiens* on heavy grey-brown clay loams – flat to swale areas adjacent to riparian channels of Allingham Creek.
5. Riparian	Areas associated with Allingham Creek channels- *E.* tesselaris, E.brownii, *M. bracteatus, Allocasuarina spp*. over *D. sericeum/D. aristatum/B. decipiens*. Numerous creek channels, some with semi-permanent water, and associated heavy loam stream levees.
6. Basalt ridges	Rocky basalt ridges and walls –*E. crebra/C.erythrophloia /C. dallachiana* with shrubby mid-story of *Carissa spp., Bursaria incana, Erythroxylum* spp., *Atalaya* spp. over *B. ewartiana, H. contortus, H. triticeus and Melenis repens.* Large basalt rocks present.

Fanning River vegetation communities – July 2000

1. Ironbark/bloodwood	*E. crebra/C. erythrophloia* over *B. ewartiana, H. contortus, C. fallax*. Dominated in some areas by *B. pertusa*. Undulating topography on Dalrymple neutral red duplex soils).
2. White Gum Flats	*C. tessellaris, E. playphylla, E. tereticornis, C. dallachiana* over B. *ewartiana, H. contortus, B. decipiens, D. sericeum* . Sandy loam alluvial flats adjacent to larger creeks.
3. Sandalwood/ shrubby	*E. brownii, C. clarksonii* over mid-story of *Eremophola mitchellii, Bursaria spp., Atalaya* spp., *Carissa* spp. in gullies and hillslope breakaways on skeletal soils or eroded landscapes.
4. Box Flats	*E.brownii* and scattered *C. dallachiana* over mid story of scattered *Carissa, Atalaya* and *E. mitchellii*. Usually heavy soils on lower slopes, associated with middle order streams.
5. Riparian	Creek line areas – *Melaleuca bracteata, Allocasuarina* spp. *Lophostemon* spp., often with mid-story of rubbervine (*Cryptostegia*) over *Arundinella* sp., *B. decipiens* and forbs.
6. Mixed Euc./rocky hills	*E. crebra, C. clarksoniana, C. erythrophloia, C. dallachiana* with mid story of *Bursaria, Petalostigma* spp., *Carissa* and *Atalaya* over *H. contortus*, *Enneapogon* spp., *Aristida* spp., *Themeda* spp. on rocky/stony hill-slopes around Mt. Success and other hilly areas.
7. Limestone ridge	Broadleaf vine thicket scrub associated with limestone ridge in NW section of paddock. Over-story of *Brachychiton* spp., *Acacia brewsteri*, *Lophostemon* spp. *Owenia* spp, *Terminalia* spp, over mid-story of vines, *Cajanus* spp. *Indigofera* spp and grass layer dominated by *H. contortus, Melenis repens, B. ewartiana, T. triandra* and *B. pertusa*.
8. Gully systems	Mixed Eucalypt and shrubs (*Atalaya, Carissa, Eromophola, Cryptostegia*) over annual and perennial grasses mostly dominated by *B. pertusa* but also *H. Contortus, B. ewartiana*, *M. repens*. Associated bare scalds, rills and major gully systems.

VEGCOM codes used at November 2000 Botanal transect sampling

At the November 2002 sampling the previously separate VEGCOM codes for each study paddock were consolidated into a single VEGCOM code list for standardization purposes. The new codes were as follows. Reconciliation tables linking the July 2000 and November 2000 VEGCOM codes can be found below and also in the "main_data_notes" worksheets of November 2000 Botanal data files.

Table 6.4: List of VEGCOM codes and descriptors used at November 2000 sampling

VEGCOM	Description	Virginia Park	Fanning River	Fletchervale
1	IBBW- granodiorite systems	yes	yes	no
2	IBBW – stony granodiorite	yes	yes	no
3	IBBW - red basalt plains	no	no	yes
4	BOX flats - granodiorite systems	yes	yes	no
5	BOX flats - red basalt system	yes	yes	no
6	RIPARIAN - granodiorite systems	yes	yes	no
7	RIPARIAN - red Basalt system	no	no	yes
8	GULLY SYSTEMS – granodiorite	yes	yes	no
9	S/WOOD SCALDS - granodiorite	yes	yes	no
10	WHITEGUM/ALLUV granodiorite	yes	yes	no
11	BLACKSOIL PLAINS - basalt soils	no	no	yes
12	BASALT COLLUVIUM - basalt soils	no	no	yes
13	BASALT RIDGES - red basalt system	no	no	yes
14	STONY HILLS/MIXED EUC	no	yes	no
15	LIMESTONE/VINE SCRUB	no	yes	no

Detailed VEGCOM code descriptions – November 2000 sampling

1. Ironbark/bloodwood granodiorite systems (Vpark and Friver)
   E. crebra/C. erythrophloia over *B. ewartiana, H. contortus, C. fallax,* now dominated by *B. pertusa*. Undulating topography on Dalrymple neutral red duplex soils.

2. Ironbark/bloodwood Stony Goldfields (Vpark and Friver)
   E. Crebra/C. erythrophloia/C. dallachiana over *B.ewartiana, Enneapogon spp., H. contortus* on undulating topography with rocky/stony surface – goldfields neutral red duplex soils.

3. Ironbark / bloodwood basalt systems (Fvale only)
   Crebra/C. erythrophloia/C. dallachiana (Ironbark/bloodwood) over *B. ewartiana*, *D. sericeum, H. contortus* (with significant invasion of *Cenchrus and Urochloa* spp) on rocky red basalt soils in flat to undulating topography of basalt plains or plateaux.

4. Box Flats granodiorite systems (Vpark and Friver)
   E. brownii and scattered *C. dallachiana* over mid story of scattered *Carissa, Atalaya* and *E. mitchellii*. Usually heavy soils on lower slopes, associated with middle order streams.

5. Box flats basalt systems (Fvale only)
   E. brownii over *D. sericeum, D. aristatum, B. decipiens* on heavy grey-brown clay loams – flat to swale areas adjacent to riparian channels of Allingham Creek.

6. Riparian – creeks granodiorite systems (Vpark and Fvale)
   Major creek lines dominated by *E. tesserlaris, E. teriticornis, E. platyphylla* and *Melaleuca leucodendron, Melaleuca bracteata, Allocasuarina* spp. and *and Lophostemon* spp. over mixed perennial grasses. Grasses such as B. *pertusa* and *U. mosambicensis* dominate open areas whilst *Arrundinella* sp. occupies creek banks. *Cryptostegia* and other exotic weeds often prevalent in mid-story.

7. Riparian – creeks basalt systems (Fvale only)
   Areas associated with Allingham Creek channels- E. tesselaris, *E.brownii*, *M. bracteatus, Allocasuarina spp*. over *D. sericeum/D. aristatum/B. decipiens*. Numerous creek channels, some with semi-permanent water, and associated heavy loam stream levees.

8. Gully systems granodiorite systems (Vpark and Fvale)
   Deep gullies often characterized by mixed Eucalypt and overstory and shrubby understory of *Carissa, Atalaya, Eromophola mitchellii and cryptostegia.* Understory grasses usually dominated by *B. pertusa* but *B.*

	ewartiana, H. contortus and *M. repens* may also be present where little grazing.
9. Sandalwood scalds granodiorite systems (Vpark and Fvale)	Usually scalded or eroded sodic soil areas dominated by box (E brownie) overstory, false sandalwood (*E. mitchellii*) and *Carissa (*mid-story with poor grass cover usually dominated by *B. pertusa, Sporobolus* spp. and other annuals. Highly susceptible to erosion from grazing impacts.
10. White Gum Flats granodiorite systems (Vpark and Fvale)	Alluvial flats close to major creek systems, dominated by an overstory of *C. tessellaris, E. playphylla, E. tereticornis, C. dallachiana* over B. *ewartiana, H. contortus, B. decipiens, D. sericeum* .
11. Black Soil Plains basalt systems (FVale)	Scattered *E. brownii* over *D. sericeum/D. aristatum, P.decompositum* on heavy grey cracking clay soils in almost treeless lower lying areas between red basalt areas and riparian zones.
12. Basalt colluvium basalt systems (FVale only)	Mixed Eucalypt (*E. crebra, C. erythrophloia, E. melanophloia, C.dallachiana)* over *B. ewartiana, B. decipiens, D .sericeum ,D aristatum.* On flat to slightly undulating country, almost rock free, with associated blacksoil depressions and gilgais and box areas. Usually in margins between red basalt. NOTE. These were later renamed basalt sediments – a more correct term.
13. Basalt ridges basalt systems (FVale only)	Rocky basalt ridges and walls –*E. crebra/C. erythrophloia /C. dallachiana* with shrubby mid-story of *Carissa spp., Bursaria incana, Erythroxylum* spp., *Atalaya* spp. over *B. ewartiana, H. contortus, H .triticeus and Melenis repens.* Large basalt rocks present.
14. Stony Hills/mixed Euc granodiorite systems (Friver only)	*E. crebra, C. clarksoniana, C. erythrophloia, C. dallachiana* with mid story of *Bursaria, Petalostigma* spp.*Carissa* and *Atalaya* over *H. contortus*, *Enneapogon* spp., A*ristida* spp. *Themeda* spp. on rocky/stony hill-slopes around Mt. Success and other hilly areas of Fanning River.
15. Limestone ridge granodiorite systems (Friver only)	Broadleaf vine thicket scrub associated with limestone ridge in NW of paddock. Over-story of *Brachychiton* spp., *Acacia brewsteri*, *Lophostemon* spp. *Owenia* spp., *Terminalia* spp, over mid-story of vines, *Cajanus* spp. *Indigofera* spp and grass layer dominated by *H.contortus, Melenis repens, B. ewartiana, T. triandra* and *B. pertusa*.

VEGCOM codes used from April 2001 Botanal transect sampling onwards

From the April 2001 Botanal transect sampling the old system of VEGCOM codes and TOPO or landscape position codes was replaced with a separate codes for dominant vegetation community (VEG) and soil type / topographic feature (SOIL/TOPO) within a 10m radius of each quadrat. This system was adopted to provide more discrimination or resolution in regard to landscape features, which may contribute to observed grazing patterns and impacts and to overcome anomalies encountered in use of broad scale VEGCOM descriptors. New codes and descriptors are listed below.

Changes from the previous coding system of July and November 2000

1. The previous VEGCOM codes, which were a combination of vegetation over-story and soil type, have now been separated into VEG and SOIL/TOPO fields for better definition of vegetation maps and interpretation of data attributes scored.

2. The previous TOPO field was removed as most of the critical info from this field will be incorporated into the SOIL/TOPO field.

Table 6.5: VEG codes and descriptors - April 2001 onwards.

VEG	DESCRIPTION	VIRGINIA PARK	FANNING RIVER	FLETCHERVALE
1	Ironbark/Bloodwood	yes	yes	yes
2	Box	yes	yes	yes
3	Whitegum	yes	yes	yes
4	Sandalwood	yes	yes	yes
5	mixed Euc/ shrubby	yes	yes	yes
6	riparian	yes	yes	yes
7	mixed Eucalypt/broadleaf	yes	yes	yes
8	broadleaf scrub/vine thicket	no	yes	no

Table 6.6: SOIL/TOPO codes and descriptors - April 2001 onwards

SOIL/TOPO	DESCRIPTION	VIRGINIA PARK	FANNING RIVER	FLETCHERVALE
1	goldfields – granodiorite	yes	yes	no
2	stony goldfields – granodiorite	yes	yes	no
3	gully systems – granodiorite	yes	yes	no
4	scalded areas – granodiorite	yes	yes	no
5	alluvials/creek banks - granodiorite	yes	yes	no
6	sandy creek beds - granodiorite	yes	yes	no
7	steep rocky slopes/ridges	no	yes	no
8	limestone ridges	no	yes	no
9	red basalt plains/plateaux	no	no	yes
10	rocky Basalt ridges or outcrops	no	no	yes
11	basalt sediments – few rocks	no	no	yes
12	Stony colluviums / basalt margins	no	no	yes
13	blacksoil plains - almost treeless	no	no	yes
14	scalded areas / basalt margins	no	no	yes
15	gully systems – not channels	no	no	yes
16	allluvials – creek/channel banks	no	no	yes
17	creek /channel beds	no	no	yes
18	brown clay loams / box-coolibah	no	no	yes

Detailed description of VEG and SOIL/TOPO codes

NOTE: Both VEG and SOIL TOPO codes contribute to overall description of category

A. VEG Codes - all systems

VEG 1. Ironbark/ Bloodwood with little shrubby mid-story, over mixed perennial tussock grasses (in less disturbed state) dominated by *B.ewartiana, H.contortus, D.sericeum* , plus native annual grasses, legumes and forbs. In disturbed state can be dominated by exotic perennial grasses such *as B.pertusa* (granodiorite) *or C.ciliaris/U.mosambicensis* (basalt). This veg type can occur on GRANODIORITE SOIL/TOPO 1,2 and occasionally 3 and 4 and BASALT SOIL/TOPO 9 and 10 (see SOIL/TOPO descriptions for details).

VEG 2. Box - Over mixed perennial and annual grasses dominated by *B.decipiens* and *D.sericeum* in less disturbed states on both granodiorite and basalt (more *Dichanthium* in basalt systems). On grano diorite BOX areas associated mainly with heavy clay/loam poorer drained lower slope areas which are subject to surface scalding and gully erosion when highly disturbed. On basalt systems BOX areas associated with blacksoil and basalt quarternary sediment areas. Rubbervine often significant.This VEG type can occur on GRANODIORITE SOIL/TOPO 1-4 or BASALT SOIL/TOPO 11, 13, 16 and 17.

VEG 3. Whitegum – *C. tesserlaris* and/or *C.dalachiana*, and/or *C. platyphylla* and/or *E. teriticornis* over mixed perennial and annual grasses dominated by *B.decipiens, D.serecium/fecundum*, *E.procera* in undisturbed state and replaced by exotic perennials in response to sustained heavy grazing. Usually associated with sandy-loam levee areas associated with higher order streams, particularly in granodiorite systems but occasionally adjacent to riparian areas in basalt systems. This VEG type can occur on GRANODIORITE SOIL/TOPO 4/5 and BASALT SOIL/TOPO 11 and 16

VEG 4. Sandalwood – Shrubby areas dominated by *E.mitchellii* and *Carissa spp*, with *Atalaya, Flindersia* and other shrubs often present. On granodiorite systems usually associated with heavily scalded lower slope areas and bigger gully systems. On basalt systems, usually associated with stony colluvial margins between red basalt and heavy claysoil areas, often at bottom on basalt ridges. Rubbervine often present. This VEG type associated with GRANODIORITE SOIL/TOPO 3 and 4 and BASALT SOIL/TOPO 12.

VEG 5. Mixed Shrubby - Usually Ironbark/bloodwood or mixed Eucalypt overstory with significant mixed shrubby mid-story dominated *by Carissa, Atalaya, Erythroxylum , Eremophola mitchellii* and other shrubs. On granodiorite systems usually associated with dissected country, characterized by significant gully systems. May be confined to actual gully areas or skeletal slopes in upper/mid-slope areas but more extensive in lower slope dissected areas. Has similar characteristics to SANDALWOOD VEG 4 but not confined to scalded areas or dominated by *E. mitchellii*. On basalt systems can be associated with rocky basalt outcrops and ridges or colluvial margins. This VEG type associated with GRANODIORITE SOIL/TOPO 3 and 7 and BASALT SOIL/TOPO 11 and 12.

VEG 6. Riparian - Mixed creek bank and adjacent new levee veg community with overstory dominated on granodiorite systems *by M. bracteatus, M. leucodendron, Allocasuarina spp., Lophostemon spp* and *E.teriticornis* over mixed perennial and annual grasses dominated by *D. fecundum, B. decipiens, E. procera* and *Arundinella* in less disturbed states and *B. pertusa* in heavily grazed areas. On basalt systems overstory dominated by *M.bracteatus, Allocasuarina spp, E. brownii, C. tesserlaris* and other Euc species over mixed perennials dominated by *D. fecundum, D.aristatum, B. decipiens, Arindinella* and *Capilipedium spp* (replaced by *B.pertusa, U. mosambicensis* and other exotics with heavy grazing). This VEG type associated with GRANODIORITE SOIL/TOPO 5 and 6 and BASALT SOIL/TOPO 16 and 17.

VEG 7. Broadleaf Scrub/Vine Thicket - Mixed broadleaf overstory dominated by Lyspohyllum, Brachychiton, Owenia, Terminalia, Alphitonia and other species with mid-story of leguminous shrubs such as Cajanus, Indigofera and Tephrosia spp and malvaceous shrubs such as Hibiscus, Sida, Abelmoschus and other. Understory either absent under closed canopy or dominated by twining legumes and forbs and mixed native and exotic grasses where opened by disturbance. This veg type almost exclusively associated with limestone ridge areas and isolated hills within the Fanning River study paddock. Although some of these tree and shrub species occur in isolation on basalt ridges, this Veg type Fanning River only, TOPO 7.

VEG 8. Mixed Eucalypt/Broadleaf – Mixed Eucalypt and broadleaf overstory associated with steep rocky slopes or hilltops, mainly on granodiorite systems. Overstory usually dominated by a mixture of bloodwoods (C. erythrophloia, C. clarksoniana), scattered E.crebra, C. dalachiana and box (E. Normantensis) plus some broadleaf species such as Petalostigma, Brachychiton and others. It is often an integrade between Ironbark/bloodwood and broadleaf scrub veg types on Fanning River. Mid-story can be shrubby (Atalaya, Erythroxylum etc) or open, over mixed perennial tussock grass. This VEG type associated with GRANODIORITE SOIL/TOPO 8 only.

SOIL/TOPO codes – Granodiorite systems

SOIL/TOPO 1. Goldfield/Dalrymple – normal/undulating - Granodiorite duplex soils over mixed native perennial grasses, which are usually replaced by *B. pertusa* after sustained heavy grazing. Usually undulating country with sandy/loamy surface and little stone, though occasional granite outcrops occur. Usually dominated by VEG 1 (ironbark bloodwood).

SOIL/TOPO 2. Stony Goldfields - Similar to SOIL/TOPO 1 but with distinct stony soil surface and frequent rocky outcrops. May be associated with areas of increased slope and/or gullying and sol surface loss in upslope areas.VEG overstory mainly ironbark/bloodwood with understory often characterized by presence of *Enneapogon* species and other increaser perennial and annuals, unless dominated by *B. pertusa*.

SOIL/TOPO 3. Gully systems - On upper and mid-slope these may be deep but narrow systems, where the overstory and mid-story veg is basically ironbark/bloodwood while the understory is degraded and either bare or dominated by exotics. On the lower slopes extensive gully systems may be characterized by a degraded box and/or whitegum overstory and a mid-story dominated by *Carissa, Atalaya, Eromophola mitchellii* and othershrubs. Understory grasses are usually dominated by pertusa.

SOIL/TOPO 4. Scalded Areas - Usually severely degrade lower slope areas characterized by extensive sheet, rill and gully erosion. Overstory often scattered (or dead) box with shrubby mid-story dominated by *E.mitchellii* and *Carissa spp.* Where scalds are severe there are few live trees and only scattered shrubs. Grass layer is absent or dominated by *B. pertusa* or *Sporobolus spp*. with occasional islands of perennial tussock grasses

SOIL/TOPO 5. Alluvial Soils/ Creek Banks - Sandy/loamy levee areas adjacent to mid/ higher order streams. Usually associated with mixed whitegum veg system (VEG 3) over a grassy understory of mixed perennial grasses. These areas are often dominated by exotic perennials and weedy forbs, due to proximity to water points. They can be associated with VEG type 3 and 4 on granodiorite system. These areas can also contain significant rubbervine and broadleaf weed infestation.

SOIL/TOPO 6. Sandy Creek Bed - Associated exclusively with granodiorite riparian (VEG 6) this SOIL/TOPO is provided to discriminate between creek bank (riparian) and usually bare sandy creek beds in larger streams.

SOIL/TOPO 7. Steep Rocky Hillslopes or Ridges - Basically restricted to the steeper hillslopes of Fanning River paddock – but excluding the limestone ridge (SOIL/TOPO 8). The slopes of Mt. Surprise are also included in this code.VEG type 8 is almost exclusively associated with this system, but it can also contain some VEG 1 (IB/BW) or VEG 7 (broadleaf scrub) on some hilltops.

SOIL/TOPO 8. - Limestone Ridge – Restricted to Fanning River paddock only and associated exclusively with VEG 7 (broadleaf scrub/vine thicket). Rocky limestone ridge and hills supporting dry rainforest closed canopy forest.

SOIL / TOPO codes - Basalt systems

SOIL/TOPO 9. Basalt Plains/Plateau - Basaltic red clay loams on flat to slightly undulating terrain with some surface rock and rocky outcrops, supporting mainly IB/Bwwith scattered mid-story *of Carissa, Bursaria, Maytenus* and *Atalaya* over mixed perennial tussock grasses dominated by *B. ewartiana*. Where disturbed, exotic species *U.mosambicensis* and *C.ciliaris* often dominate.

SOIL/TOPO 10. Rocky Basalt Ridges And Outcrops - Includes basalt wall areas and outcrops within SOIL/TOPO 9. Similar IB/BW overstory with addition of scattered *C.dalachiana , Petalostigma, Alphitonia, Bursaria* and shrubby mid-story species such as *Carissa, Atalaya, Erythroxylum, Maytenus* and *Santalum*. Grassy layer often characterized by presence of *H.triticeus*. The exotic grass *M.repens* is often prominent in these areas.

SOIL/TOPO 11. Basalt Sediments - Formally described as **basalt colluvium**. These are areas of depositional basalt derived soils characterized by a mosaic of almost stone free brown loams and heavy clay gilgais or swales supporting a mixed Eucalypt overstory of *E. crebra, E. melanophloia, E.brownii, C.erythrophloia* and *C.dalachiana*. over an open mid-story and grassy layer dominated by *B.decipiens, D.sericeum* and *D.aristatum* with some *B.ewartiana*.

SOIL/TOPO 12. Basalt Margins - These areas are stony colluvial margins between red basalt soils an transitional basalt sediment areas (SOIL/TOPO 11). They support a mixed Eucalypt overstory of *E.crebra, C.dallachiana, C.erythrophloia* and *E.brownii* over a usually shrubby mid-story of *Atalaya, Bursaria, Carissa, E.mitchellia, Flindersia* and *Maytenus*. The grass layer is often scattered and dominated by Enneapogon, Sporobolius, Eragrostis and Melenis along with native forbs and legumes.

SOIL/TOPO 13. Black Soil – Almost treeless cracking claysoil plains or depressions dominated *by D. sericeum, P.decompositum, A. squarosa, D.aristatum* and *Eriochloa spp*.

SOIL/TOPO 14. Scalded Areas - Rare in basalt systems, but occasionally associated with SOIL/TOPO 9 and 12 where surface erosion has removed loamy top layer exposing heavier sodic clay subsurface after sustained heavy patch grazing.

SOIL/TOPO 15. Gully Systems - Rare in basalt systems but does occur in small areas adjacent to basalt margins associated with VEG 4 and 5.

SOIL/TOPO 16. Alluvial Soils – Assocated with creek or channel banks adjacent to higher order streams. Usually loamy sediments rather than sandy. Overstory usually box but occasionally whitegum (VEG 3).

SOIL/TOPO 17. Creek/Channel Bed – Mid-stream dry channel beds – usually heavy soil – mostly bare, but occasionally supporting couch lawns.

SOIL/TOPO 18. Brown Clay Loams - Associated with box veg communities (veg 2) which occur on lower slopes between basalt margins , basalt sediments and riparian areas bounding Allingham Creek. Overstory dominated by Reid River Box (*E.brownii)* and Coolibah (*E.coolibah*?) with understory dominated by *D. sericeum, P.decompositum, A. squarosa, D.aristatum* and *Eriochloa spp*.

Table 6.7: Reconciliation of VEGCOM, VEG and SOIL/TOPO codes from all samplings

	JULY 2000	NOV. 2000	APRIL 2001 ONWARD	
PADDOCK	***VEGCOM***	**VEGCOM**	**VEG**	**SOIL/TOPO**
VPARK	1	1	1	1
FRIV	1	1	1	1
FVALE	1	3	1	9
VPARK	2	8	5	3
FRIV	2	10	3	5
FVALE	2	12	5	11
FVALE	2	12	2	11
VPARK	3	6	6	5
VPARK	3	10	3	5
FRIV	3	9	4	4
FVALE	3	11	2	13
VPARK	4	4	2	4
FRIV	4	4	2	4
FVALE	4	5	2	18
VPARK	5	9	4	4
FRIV	5	6	6	5
FRIV	5	6	6	6
FVALE	5	7	6	16
FVALE	5	7	6	17
VPARK	6	2	1	2
FRIV	6	14	7	7
FVALE	6	13	1	10
FVALE	6	13	5	10
FRIV	7	15	8	8
FRIV	8	8	5	3

Use of 4 m^2 reference quadrats for training and calibration

At each of the three (3) study paddocks (Virginia Park, Fletchervale and Fanning River) a set of 2m*2m reference quadrats were established for initial and ongoing observer training and to generate a series of photo standards. The number of quadrats varied slightly between paddocks but was at least 10 in each case. Actual numbers were:- Virginia Park = 13, Fletchervale = 11, Fanning River = 11.

OBSERVERS - Jeff Corfield, Peter Allen, Peter Fry, Taoufik Ksiksi, with John Gross present for Virginia Park.

Quadrats were selected to try and cover the range of biomass yields, projected covers, defoliation and pasture types likely to be encountered within the paddock – within the constraint of easy accessibility for reference during each sampling exercise.

Each quadrat was initially marked by placing metal fence droppers in each corner and a permanent steel picket at the centre, on which was recorded the quadrat number. At the conclusion of the calibration exercise the temporary metal droppers were removed for stock safety reasons.

Each reference quadrat was photographed (by Taoufik KsiKsi, QDPI, Charters Towers) both obliquely from one side and as close to vertical as possible from the back of a quad bike (same direction) for future reference and for generation of photo standards to use in future sampling exercises. Taoufik retains this photo record.

Observer training and calibration using reference quadrats

This involved 3 components in a “double sampling” approach

1. All observers, in the process of choosing the range of reference quadrats, arrived at a mutually acceptable scale for yield estimates (to cover the range of yields likely to be encountered). Other variables such as cover, defoliation and greenness were either scored as a percentage or on a pre-determined rating scale. For each quadrat, observers then settled on a consensus score for the major variables to be recorded. Individual observer scores were also recorded for future reference.

2. Within each 2m*2m quadrat each observer then scored each 1m*1m sub-quadrat in the same order, recording variable scores on the same scales used for the 2m*2m quadrats. This exercise was to derive individual observer relationships between the more familiar $1m^2$ quadrat size and $4m^2$ reference quadrat size and also to provide immediate “in the field” feedback to observers about effects of spatial scale on observations. At the end of this exercise observers compared their component $1m^2$ scores with the corresponding $4m^2$ scores and adjusted their individual estimations accordingly.

3. At the end of exercise 2 a set of $1m^2$ standards were scored by each observer. A sub-set of these 1m standards was photographed to derive cover and greenness values and the full set was harvested to derive biomass values. This data was then used to generate individual observer regressions for biomass yield, cover and greenness. Defoliation ratings could not be calibrated in this way, but between-observer variation could be monitored . Results from this calibration exercise were then fed back to observers to assist in refining estimation techniques, and reducing between observer variation.

On-going use of reference standards

At each field sampling exercise, each observer re-scored the full set (or a sub-set) of reference standards as part of the “double sampling” training and calibration process. If possible, both separate whole quadrat and component sub-quadrat scores are recorded as in initial calibration exercise. During the first sampling exercise (June/July 2000) This latter exercise was unnecessary, as field sampling followed straight on after establishment of reference quadrats.

If structure or biomass yield of any reference quadrat changes significantly during the season, due to heavy grazing or disturbance, consideration should be given to adding additional reference quadrats to original set. Reference quadrats were also re-photographed at each sampling period as a record of phenology and seasonal conditions.

Note: The herbage species list established in July 2000 and added to in November 2000 continued to be used at all subsequent samplings.

Vegetation sampling instruction sheets

Burdekin Catchment Study – Sampling Procedure – 1st Sampling July 2000

1. Locate sample site using “go to” facility for predetermined weigh point
2. Place dropper close to centre of sample site
3. Each observer to run 100m tape out in opposite directions (either NSEW or Dslope/upslope or cross-slope)
4. Walking back along 100m tape line, locate each pre-determined quad position
5. Using HP spreadsheet program, record parameters & variables listed below
6. Repeat procedure for 2nd set of sampling arms at sample site

Burdekin Catchment Study – Sampling Procedure – 2nd Sampling Nov 2000

1. A set of predetermined TRANSECTS will be selected, each with START (A) and END (B) waypoints already loaded into each GPS as waypoints and / or routes.
2. The entire length of each transect will be scored in SECTIONS of 200m each (or part thereof at the end of each transect).
3. Observers will work in pairs, with each observer scoring 2*200m sections at a time, leap-frogging along each transect, using the quad-bike and GPS “go-to” facility to locate each new start point.
4. Within each transect SECTION, observers will score TEN 2m*2m quadrats whose locations have been pre-selected in a stratified random fashion. The START and END of each 200m SECTION will be recorded as GPS waypoints using the MARK facility on each GPS. The associated waypoint number MUST be recorded against the START and END records on the HP.
5. Distances between QUADRATS along transect sections will be PACED. Quadrat position sets will be in PACES not metres. Observers MUST write their NAMES on each quadrat position sheet they use and MARK OFF each quadrat set with TRANSECT and SECTION number and RETAIN SHEET for later use.
6. If there is less than 200m in the last SECTION scored, just score up to the number of quadrats within the distance available and record the END GPS weigh point at the end of the transect.
7. Using HP spreadsheet program, record parameters & variables listed. Fill in each variable cell to ensure no data is missed and avoid ambiguity in data interpretation.

Note: November 2000 instructions remained the same for subsequent scorings

Table 6.8: Description of variables recorded in hillslope-scale vegetation measurements

Variable	Description	Reference	Units or Categories
SITE	Study paddock code		FRIVPAT=Fanning River patch study
DATE	Sampling date		dd-Mon-yy
TRANSECT	Patch transect number - refers to paddock scale transects on which patch study transects located		1-13
SECTION	100 m section of transect bounded by start and end waypoints		1-3
BURN	Status of quadrat in relation to recent burning in paddock		Categorical variable 1=unburnt, 2= burnt
WAYPOINT	GPS waypoint number – recorded at start and end of each 100m patch transect		UTM GW84 datum 55k zone
PATCH	Patch Type - see separate code and description list		Categorical. See code descriptions in this appendix.
DISTANCE	Distance from start of patch transect section		(meters and decimetres)
COVER	Mean total projected cover (foliar plus litter cover + rocks) for patch		percent
PAST_HT	Mean pasture height for patch - to flag leaf, excluding inflorescences		centimetres
DOM_ SP1	Most dominant pasture species or species group in patch (Botanal DWR method)	BOTANAL Tothill et al (1978)	ID number
SP1_PERC	Estimated percentage biomass of dom_sp1		percent
DOM_SP2	Second most dominant species or species group in patch (Botanal DWR method)	BOTANAL Tothill et al (1978)	ID number
SP2_PERC	Estimated percentage biomass of dom_sp2		percent
DOM_SP3	Third most dominant species or species group in patch (Botanal DWR method) – used from Sep 2001 onward	BOTANAL Tothill et al (1978)	ID number
SP3_PERC	Estimated percentage biomass of dom_sp3 – used from Sep 2001 onward		percent
YIELD_EST	Mean standing crop biomass (comparative yield estimate) – used from Sep 2001 onward	BOTANAL Tothill et al (1978)	0-100 rating scale
DEFOL	Mean defoliation rating for patch on a 0-5 scale – used from Sep 2001 onward	Andrew (1986)	0-5 scale 0=nil, 1=<5% 2=5-25% 3=25-50% 4=50-75% 5=>75%
MAX_DIAM	Diameter of longest axis of significant bare or grazed patch – used for July 2001 only		centimeters
MIN_DIAM	Diameter of shortest perpendicular axis of significant bare or grazed patch - used for July 2000 only		centimeters

Table 6.9: Record of variables recorded at each scoring – July 2001 - September 2002

VARIABLE	JULY 2001	SEPT 2001	JAN 2002	APRIL 2002	SEPT 2002
SITE	yes	yes	yes	yes	yes
DATE	yes	yes	yes	yes	yes
TRANSECT	yes	yes	yes	yes	yes
SECTION	yes	yes	yes	yes	yes
PATCH	yes	yes	yes	yes	yes
DISTANCE	yes	yes	yes	yes	yes
WAY_PT	yes	yes	yes	yes	yes
COVER	yes	yes	yes	yes	yes
PAST_HT	yes	yes	yes	yes	yes
DOM_SP1	yes	yes	yes	yes	yes
SP1_PERC	yes	yes	yes	yes	yes
DOM_SP2	yes	yes	yes	yes	yes
SP2_PERC	yes	yes	yes	yes	yes
DOM_SP3	no	yes	yes	yes	yes
SP3_PERC	no	yes	yes	yes	yes
YIELD_EST	no	yes	yes	yes	yes
DEFOL	no	yes	yes	yes	yes
MAX_DIAM	yes	no	no	no	no
MIN_DIAM	yes	no	no	no	no

Changes to recording methodology at second scoring – September 2001

At the second scoring occasion, the following changes were made to variables recorded and recording methodology.

1. Standing crop herbage biomass (Botanal comparative yield method) was added
2. Bare and grazed patch maximum and minimum diameters were abandoned
3. Dominant species variables increased from first two to first three.
4. Herbage defoliation rating (Andrew 1986) was added
5. Estimation of all variables was confined to a 1m wide belt transect along tape center line
6. Additional patch types were also recorded (see consolidated list below)

Addition of further patch transects – January 2002 scoring

Further patch transects were established along Botanal transects 8, 9 and 13 during the January 2002 scoring, to record temporal changes in patch dynamics around water point locations. For both transects 8 and 9 these took the form of 3 contiguous 100m patch transects running out from the water trough near where both botanal transects commence. On botanal transect 13, they consisted of two contiguous running along the transect line from transect waypoint 13A towards 13B, and a further two 100m patch transects placed on both unburnt and recently burnt sections several hundred meters further along the Botanal transect (see transect descriptions and location details in appendix 1 of this document). As with previously established patch transects, start and end locations were marked by trees or wooden pegs marked with flagging tape and GPS position waypoints recorded.

Data variables recorded remained the same as for September 2001, with further patch types added to cover the impact of burning and influence of previously grazed or recovering bare patches on patterns of subsequent patch grazing (see consolidated list and description of patch types at the end of this document). A WAYPOINT field was also added to the data collection spreadsheet from January onwards.

Detailed Descriptions of Pasture/ Patch Characterization Variables

DIAM_MAX and DIAM_MIN - Bare and grazed patch diameters

At the July 2001 scoring the longest and shortest diameters of each bare or grazed patch encountered within each transect were recorded as a measure of patch dimensions. Variables associated with all other patch types were recorded only within the 1m belt transects along the tapeline.

PAST_HT - Mean pasture height

Mean pasture height was estimated by averaging several height measurements across each patch. Pasture height was taken from the top of the vegetative layer, excluding inflorescences.

COVER - Mean total projected cover

Mean total projected cover - the total of foliar and litter cover – was estimated across the entire patch in the case of bare and grazed patches and the 1m wide belt transect in the case of all other patch types.

DOM_SP1, DOM_SP2, DOM_SP3 - Dominant species or species groups

The identity code of the first three dominant pasture species or groups (determined by Botanal dry weight rank method (Tothill, 1978) was recorded (see species list below).

SP1_PERC, SP2_PERC, SP3_PERC - Estimated percentage contribution of dominant 3 species or species groups using Botanal percentage rank method (Tothill et al., 1978)

YIELD_EST - Estimated standing dry biomass – using Botanal comparative yield estimate technique (Tothill et al., 1978). Estimates converted to kg/ha dry matter using regressions derived from calibration standards.

DEFOL – Estimated herbage defoliation **–** using 0-5 rating scale (Andrew, 1988)

Definitions and descriptions of patches

For the purposes of this study a “patch” was defined as an area usually exceeding 1m in diameter along the length and breadth of the belt transect, which exhibits common definitional features in respect to cover, biomass, species composition and grazing score across the majority of the patch area. The exceptions to this were when cattle pads, small gullies, rocks and large logs were recorded along transects – these being commonly <1m in width.

Thus, in the case of **bare patches**, these usually exceeded $1m^2$ and the majority of the area contained was bare ground (<10% TPC), whilst **grazed patches** usually exceeded $1m^2$, with the majority of the area contained being grazed to score 3 or more (> 50% defoliated) on the defoliation index used.

The **intermittent grazed and intermittent ungrazed patches** were defined as patches within which grazing was occurring to a greater (IG) or lesser (IU) extent across the whole area contained, but at a scale of $<1m^2$ in any portion. Intermittent grazed and ungrazed patches thus consisted of a mosaic of sub $1m^2$ grazed and ungrazed patches, with the proportion of grazed to ungrazed defining the patch type.

Transition zone patches were defined as areas straddling the margins of bare and grassed areas, where bare patch expansion often occurs in response to preferential grazing. Transitional zones can be either recovering or degrading.

Table 6.10: Description of all patch types used to date in patch transect study At Fanning River

PATCH	PATCH DESCRIPTION
GP	Grazed patch - currently being grazed TO >= 50% defoliation
UP	Ungrazed patch – < 5-10% defoliated
IG	Intermittent grazed patch (currently more grazed than ungrazed)
IU	Intermittent ungrazed patch (currently more ungrazed than grazed)
BG	Bare ground (largely scalded areas) - little herbage cover
TZ	Transition zone between edge of bare scald and grassed areas – can be degrading or recovering
CP	Cattle pad - usually bare but sometimes trampled grass if new
CC	Cattle camp - grass usually flattened or destroyed by cattle trampling
SG	Small gully –usually little herbage cover
CB	Creek bed - little herbage cover
EB	Eroded bank - usually upper creek bank damaged by erosion or cattle
LB	Lower bank - adjacent to creek bed – can have green “lawn” cover
RD	Roadway or track – little herbage cover
RK	Rock
LG	Large log or fallen tree
OGP	Old grazed patch - previously grazed patch but no recent grazing
OIG	Old intermittent grazed patch - previously impacted by intermittent heavy grazing - but no recent grazing
OIU	Old intermittent ungrazed patch - previously impacted by intermittent light-moderate grazing - but no recent grazing

Table 6.11: Species and species group codes and IDs used throughout patch transect study

BOTNUM	SPECIES	Functional group 1	Functional group 2	Functional group 3
1	*Aristida* spp.	perennial grass	native	increaser
2	*Bothriochloa decipiens*	perennial grass	native	decreaser
3	*Bothriochloa ewartiana*	perennial grass	native	increaser
4	*Chrysopogon fallax*	perennial grass	native	intermediate
5	*Dichanthium spp.*	perennial grass	native	decreaser
6	*Enneapogon sp*	perennial grass	native	increaser
7	*Heterogon contortus*	perennial grass	native	decreaser
8	*Heteropogon triticeus*	perennial grass	native	decreaser
9	*Themeda triandra*	perennial grass	native	decreaser
10	*Sorghum plumosum*	perennial grass	native	decreaser
11	Other native per. grasses	perennial grass	native	intermediate
12	*Bothriochloa pertusa*	perennial grass	exotic	increaser
13	*Melenis repens*	perennial grass	exotic	increaser
14	*Cenchrus ciliaris*	perennial grass	exotic	increaser
15	*Urochloa mosambicensis*	perennial grass	exotic	increaser
16	Other exotic grasses	perennial grass	exotic	increaser
17	*Dactylocteneum radulans*	annual grass	native	increaser
18	*Sporobolus* sp.	annual grass	native	increaser
19	*Tragus austalianus*	annual grass	native	increaser
20	Other annual grasses	annual grass	native	increaser
21	Legumes	legume	mixed	mixed
22	Sedges	sedge	native	mixed
23	Forbs	forb	mixed	mixed
24	*Panicum* spp.	perennial grass	native	decreaser
25	*Eulalia aurea*	perennial grass	native	intermediate
26	*Dichanthium aristatum*	perennial grass	native	increaser

Appendix 7. Time-series analysis using Landsat TM in the Burdekin Catchment, Qld

Kate Richardson and Robert Karfs, NT Dept. of Lands Planning and Environment

Time-series Landsat TM imagery

The purpose of this appendix is to report on an evaluation of time-series analysis as applied in the Burdekin River in selected areas, i.e. focal paddocks: Fanning River, Virginia Park and Fletchervale. Separate 1: 100,000 scale trend summary image maps have been provided for each pastoral property.

Characteristics of the imagery utilized:

- Pixel size of imagery (ie. feature resolution) – 25m.
- Projection: TMAMG55, Datum: AGD66.
- Dates analysed in the time-series – 1991, 1993, 1995, 1996, 1997 and 1998.
  - All imagery was acquired in the late dry season (August to October).
- A cover index derived from Landsat TM band 3 (visible red) was used in the analysis.

Landscape characteristics and landsat cover index

All landscapes that had relief more than 90m and a slope greater than 10% were classed as ‘rugged country’. These landscapes were not included in the analysis as grazing impact in these areas is normally minimal. In the remaining areas, land type stratification was done using land system data to separate inherently different landscapes with different surface features (eg. light versus dark coloured soils) allowing for more accurate interpretation of cover.

Over time landscapes dominated by ephemeral cover often experience greater fluctuations in cover compared to landscapes dominated by perennial cover. By examining the brightness and variation in cover indices derived from time-series Landsat satellite data, ephemeral-perennial vegetation compositions are interpreted. Cover indices summarised in graphical plots or as maps are a ‘first’ interpretation of land cover trend and condition. Ground truthing and data collection at monitoring sites are necessary to refine the relationship between land condition and cover indices.

Cover indices are numeric values derived from calibrated Landsat images that are adjusted to the regional response of a specific land type. Cover change detected by the satellite data may be due to either grazing impact, seasonal variability, fire or unmapped landscape heterogeneity. Interpretation of these data in relation to distance from water and the location of fences, roads and land types assist in determining the cause of change. Knowledge of management history gained from archived reports, photographs, and from discussion with land managers are further important sources with which to interpret cover indices and select monitoring sites.

Light coloured soils - the soils of the Goldfields land system (Fanning River and Virginia Park) were classified as bright corresponding to high spectral reflectance in TM band 3. When bright soils are covered by dry ground vegetation, the spectral reflectance is lowered, resulting in low cover index values.

Dark coloured soils - the soils of the basaltic area (Fletchervale) were classed as dark corresponding to low spectral reflectance. When these soils are covered by dry ground vegetation, the spectral reflectance is increased, resulting in high cover index values.

Finally it must also be understood that Landsat cover indices used in this analysis range from 1991 to 1998. Hence, landscape change in response to recent good rainfall years over the region is not represented.

Fanning River and Virginia Park

There are five broad land type classes within the Fanning River and Virginia Park properties based on descriptions from the Land Systems of the Dalrymple Shire. These land types are listed below and percentage area of each land type shown in Figure 7.1.

- Alluvial
- Cainozoic
- Granodiorite
- Igneous
- Sedimentary

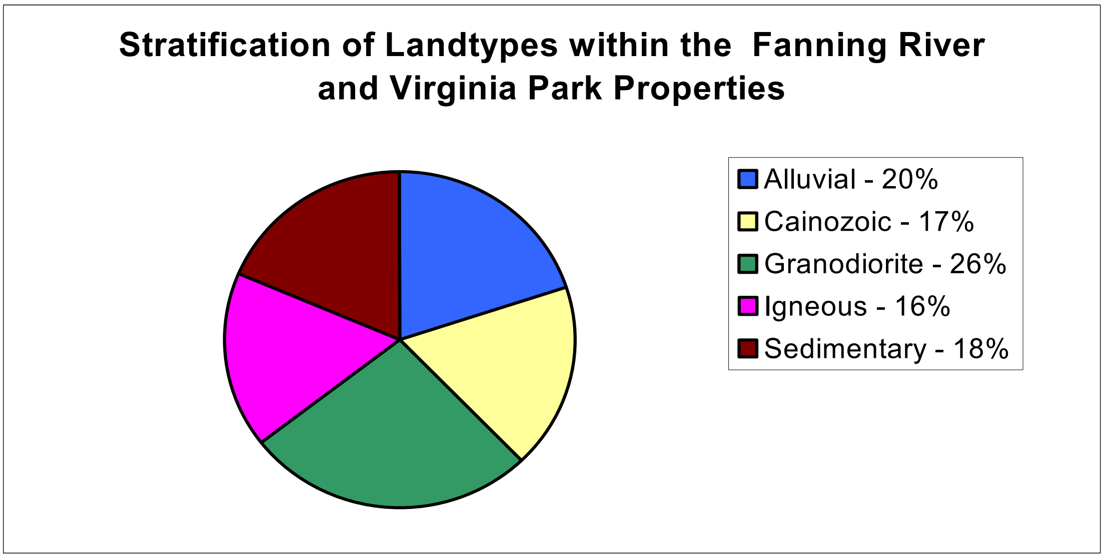

Figure 7.1: Stratification of the Fanning River and Virginia Park.

For understanding the impacts of land management and for providing representative data which to relate to Landsat cover indices, ground-based monitoring sites would need to be located on all five land types. If grazing impact is the focus, then concentrating on one or two productive land types may be the best option with less attention focused on ‘natural’ low productive land types. Figure 7.2 shows the spatial distribution of these land types over Fanning River and Virginia Park.

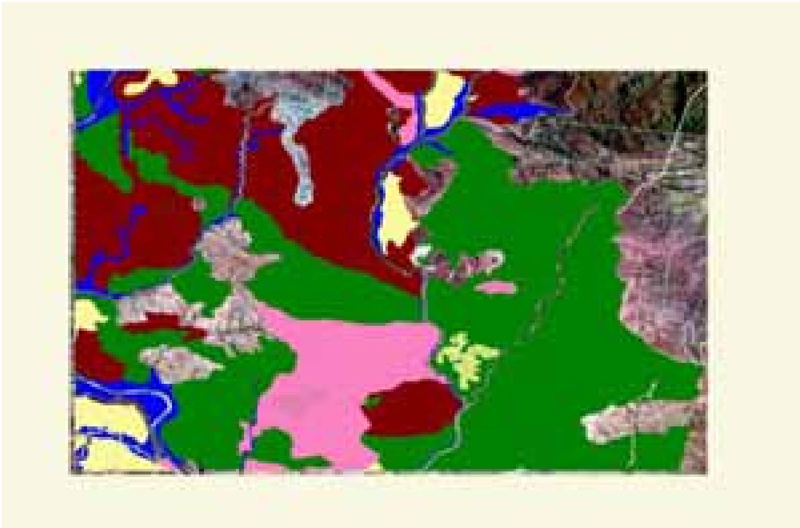

Figure 7.2: Spatial distribution of land types in the Fanning River and Virginia Park. Blue depicting alluvial soils, pink the igneous derived soils, yellow the Cainozoic soils, brown the sedimentary soils and green the granodioritic soils.

Time traces for the five land types on Fanning River and Virginia Park are shown in Figure 7.3. Our interpretation is that the Alluvial and Cainozoic land types had more cover during the 1993-96 drought compared with the other land types. But ground truthing needs to confirm that the soil colour for the Alluvial and Cainozoic land types is light coloured, similar to the three other land types.

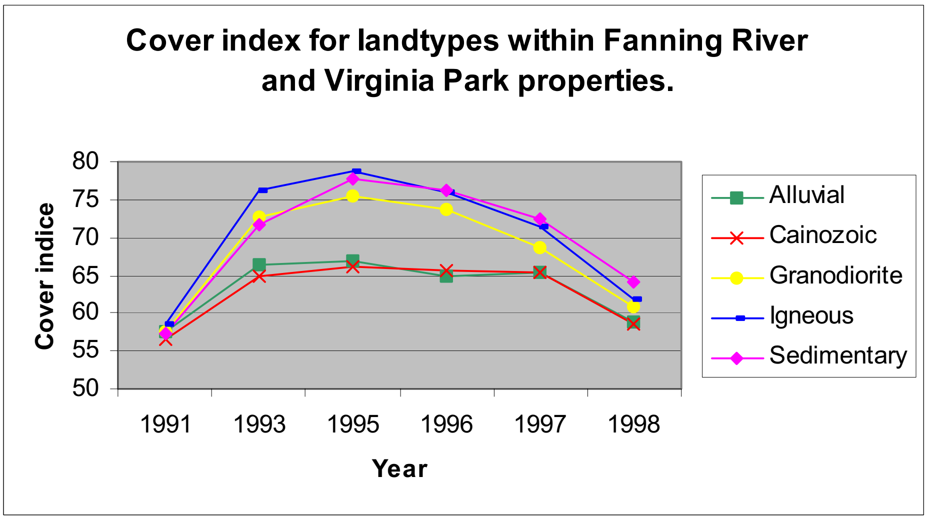

Figure 7.3: Low vegetation cover in the drought period of 1993-96, results in high cover indices for light coloured soils in Fanning River and Virginia Park.

Fletchervale

Two significant soil types were analysed within the basalt land type that comprises the Fletchervale property. These soil types are listed below and percentage area for each soil type is shown in Figure 7.4. The spatial distribution of these land types over Fletchervale is shown in Figure 7.5.

Ferrosol

Vertosol

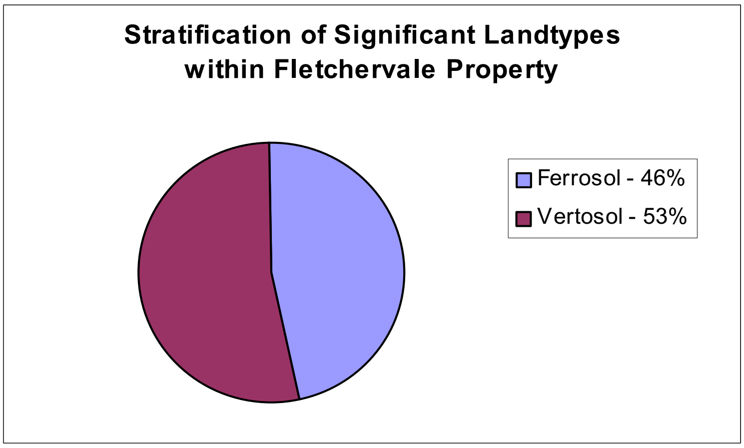

Figure7.4: Stratification of Fletchervale.

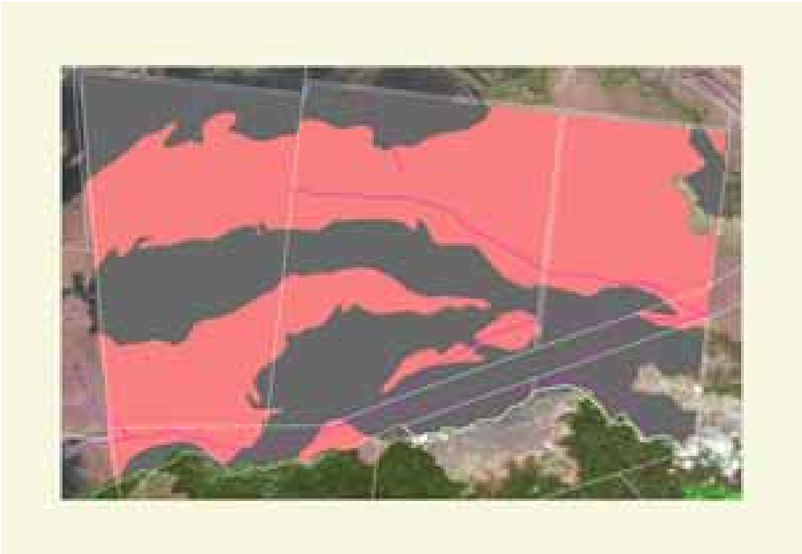

Figure 7.5: Spatial distribution of soil types in the Fletchervale. Ferrosol soils are coloured orange and the vertosol soils dark grey.

A comparison of ferrosols and vertosols on Fletchervale with similar landscapes over the entire Dalrymple Shire is shown in Figure 7.6. The time traces indicate Fletchervale had vegetation cover similar to that of the greater Dalrymple Shire before the drought period began in 1993. During the drought, cover levels over Fletchervale were slightly higher than the regional average and by 1998, two years after the drought; cover was significantly higher compared with the rest of the Shire. This relationship suggests that on Fletchervale there may have been relatively more perennial grasses on the basalt land type that survived drought and responded as seasonal conditions improved. The sharp increase in cover in 1998 is likely due to a flush of annual grasses infilling between perennial patches. Ground truthing, Landscape Function Analysis and examination of management history are required to verify this hypothesis.

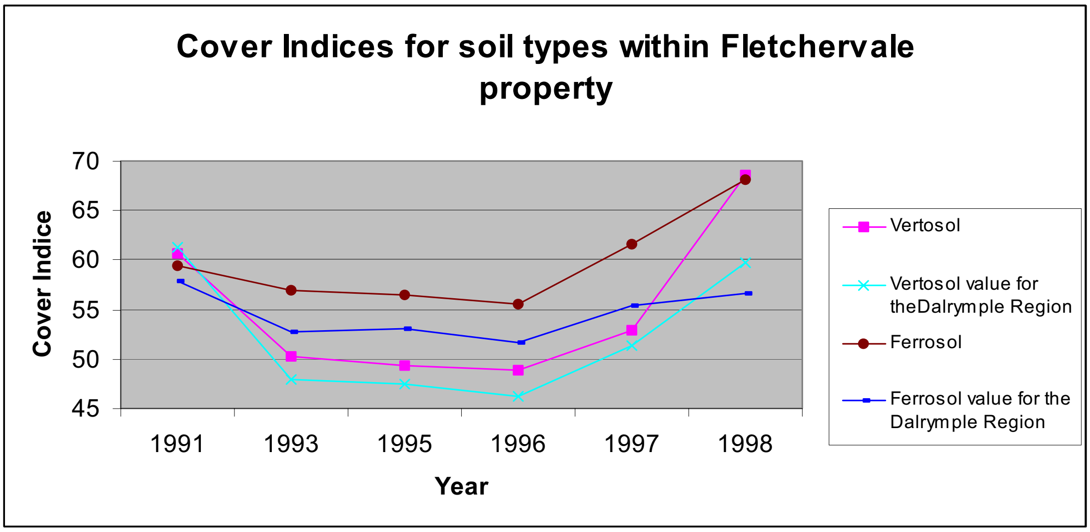

Figure 7.6: A comparison of vegetation cover on dark coloured soils of the basalt land type of Fletchervale compared with mean values for the Dalrymple Shire.

By comparing cover indices of a specific area (eg. property, paddock) with regional averages, differences in management in the context of seasonal variation may be identified. This type of intelligence assists in deciding where to look for possible monitoring sites with a key objective of finding a suite of monitoring sites on the same land type ranging in condition from poor to good from which to compare ground data and historical cover.

Trend summary image maps

Cover indices can also be summarised spatially as ‘trend summary image maps’ for discriminant analysis of vegetation cover change within stratified land types. A schematic explaining the ‘colours’ on trend summary images is shown in Figure 7.7. Table 7.1 provides further explanation of trend summary colour representation.

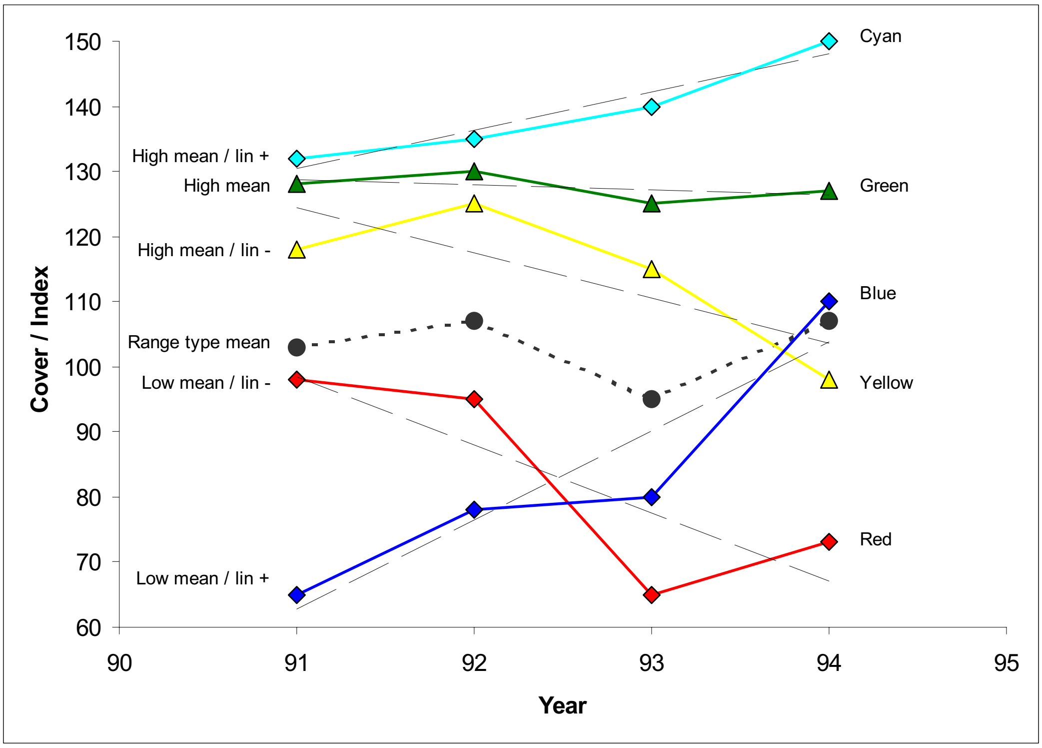

Figure 7.7: Schematic diagram of different cover responses through time, which may apply, to a pixel, or larger area. Land type mean (black dashed line) is the broad spectral response from a stratified landscape. Summaries are listed on the left and the colour equivalent is listed on the right of the diagram. Linear trend lines as thin black dashed lines are represented for each summary.

Table 7.1: – Trend summary imagery colour summation

Mean Brightness over period (displayed in intensity of green) RELATIVE to regional annual response.	**Slope**- linear trend over time RELATIVE to regional mean trend (positive trend in Blue negative trend in red).	Combined map colour using additive colour scheme – **Interpretation** based on an assumption of uniform soil colour.
GREEN: High **+**	BLUE: Positive **=**	CYAN: High cover, increasing trend over period
GREEN: High **+**	BLACK: Steady **=**	GREEN: High cover, trend close to regional average
GREEN: High **+**	RED: Negative **=**	YELLOW: High cover, trend decline over period
BLACK: Low **+**	BLUE: **Positive** **=**	BLUE: Low initial cover, increasing trend over period
BLACK: Low **+**	BLACK: Steady **=**	BLACK: Low cover relative to regional average, steady
BLACK: Low **+**	RED: Negative **=**	RED: Low cover, trend decline over period

Examples of areas over the Fletchervale property responding differently to neighbouring areas are shown in Figure 7.8. The following discussion is related to Figure 7.8.

- Fence effects and fire history are highlighted on the trend summary map. To provide a complete understanding of the area, ancillary data such as TRAPS and QGRAZE data would best be incorporated. Ancillary data such as stocking rates, location of old stock routes and fire history as well as present day infrastructure data, including watering points, fencing, and roads also need to be consulted.
- Areas showing a high cover response over time need to be assessed to determine if they are comprised of perennial grasses. A high cover response interpreted from the cover indices sometimes may be confused with weed infestation or an annual grassland with an anomalous soil surface (eg. high stoniness, silty veneer, etc.).
    - Figure 7.8a. – This example represents a fire affected landscape where the dark blue area was burnt in 1991 and the yellow area unburnt, probably separated by a fenceline. Since the blue area was burnt at the beginning of the 1990's drought, this landscape may have had little chance to establish vegetative cover until 1997 or 1998. Looking at this area now after recent good seasons would be worthwhile to identify differences (if any) on how the fire may have affected vegetation.
    - Figure 7.8b. – A fence effect is highlighted in a low cover response area (red) and no fire was mapped for this area. This area needs ground truthing.
    - Figure 7.8c. - The red area probably represents a rocky outcrop or geological difference due to the shape and intensity of the cover indices.
    - Figure 7.8d. – This area is interpreted as a stable area with relative high vegetative cover (green and cyan) requiring field verification.

Final comments

Confidence in the interpretation of Landsat time-series involves ground verification particularly at monitoring sites over a period of years. Since the relationship between ground cover and spectral data varies annually an estimate of condition using a single Landsat date, or even by comparing two dates, is problematic. Thus, sequences of Landsat imagery are used. Important landscape attributes also need to be considered such as soil type and colour, dominant vegetation type, percentage cover and amount of litter as well as surface stoniness. In addition, by examining the spatial arrangement of long-lived vegetation and soil features, Landscape Function Analysis can provide a basis which to further interpret the relationships between temporal cover indices and vegetative cover. The identification of 'desirable species' is less important as the resolution of Landsat sensors is often too coarse to detect change at the species level.

Once relationships are understood for landscapes at the site scale, rapid assessments are possible along property or regional transects to verify cover indices. The extension of detailed knowledge from sites to rapid field verification allows for a confident extrapolation across the broad landscape using only Landsat data, with less sites needed in the monitoring system.

Detecting vegetation change using time-series cover indices is a useful tool for rangeland management. Maps that can be used to help identify where grazing has resulted in poor condition landscapes or where pasture is under utilised by stock may significantly alter property management planning. Cover change histories also have useful application in research for determining rates of ecological change and understanding patterns of change over time and space.

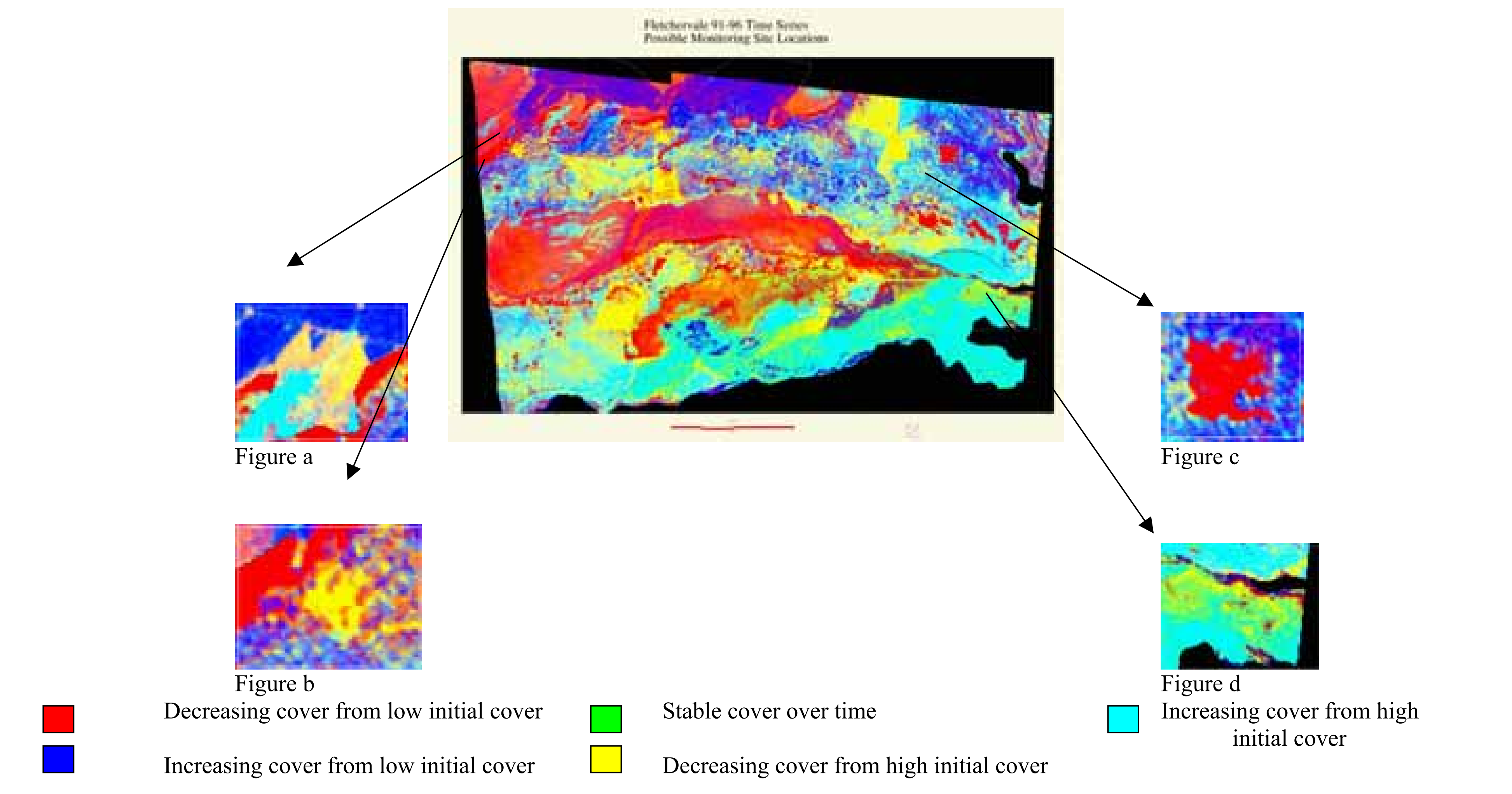

Figure 7.8: Trend summary map of Fletchervale 1991-96

Appendix 8. Rainfall simulation experiments conducted in the Upper Burdekin 1998-2002 – methodology and documentation of results

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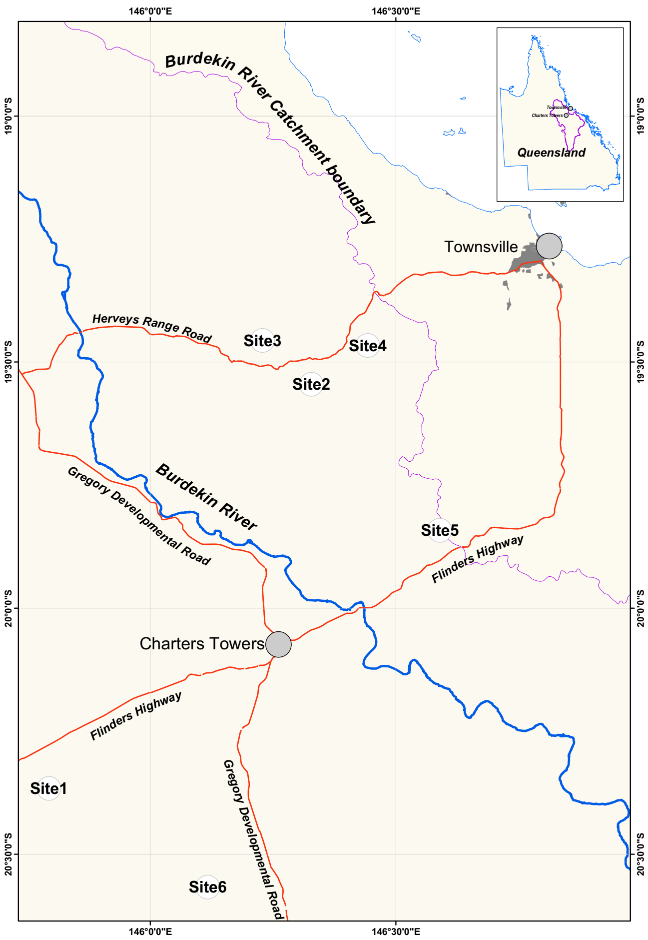
CSIRO Land and Water, Townsville.

Introduction

The purpose of this document is to provide a detailed description of the rainfall simulator developed at CSIRO Davies Laboratory, its equipment and operation. In addition, this report also provides a compilation of relevant site information and the main data obtained from all rainfall simulation experiments carried out in the period 1998 to 2001, as part of various MLA and LWRRDC/Defence Dept. funded research projects. In total, six sites ranging from 80 to 180 km east to south-east of Townsville were studied. Map 8.1 provides an indication of their location in the Upper Burdekin catchment.



Map 8.1: Locations of the six rainfall simulation sites studied in the period 1998 to 2001.

Rainfall simulator description and operation

General description

The rainfall simulator is an easily erected, mobile unit requiring only 2-3 people to setup and run. It is a capillary drop type model, capable of applying rainfall at constant rates of 25 mm/hr to ~85 mm/hr. A minimum of three experiments per day can be run with ease, with the main limitation being the amount of water that can be carried to the site. Experiments are generally run for 30 minutes per site.

A unique trailer mounted lifting device, as shown in Figure 8.1, is the key to the mobility of the unit. This is lightweight and quickly erected on site. The other major components of the system are: the top chamber, the support frame, the pumps and water supply (including a generator), and the runoff plot.

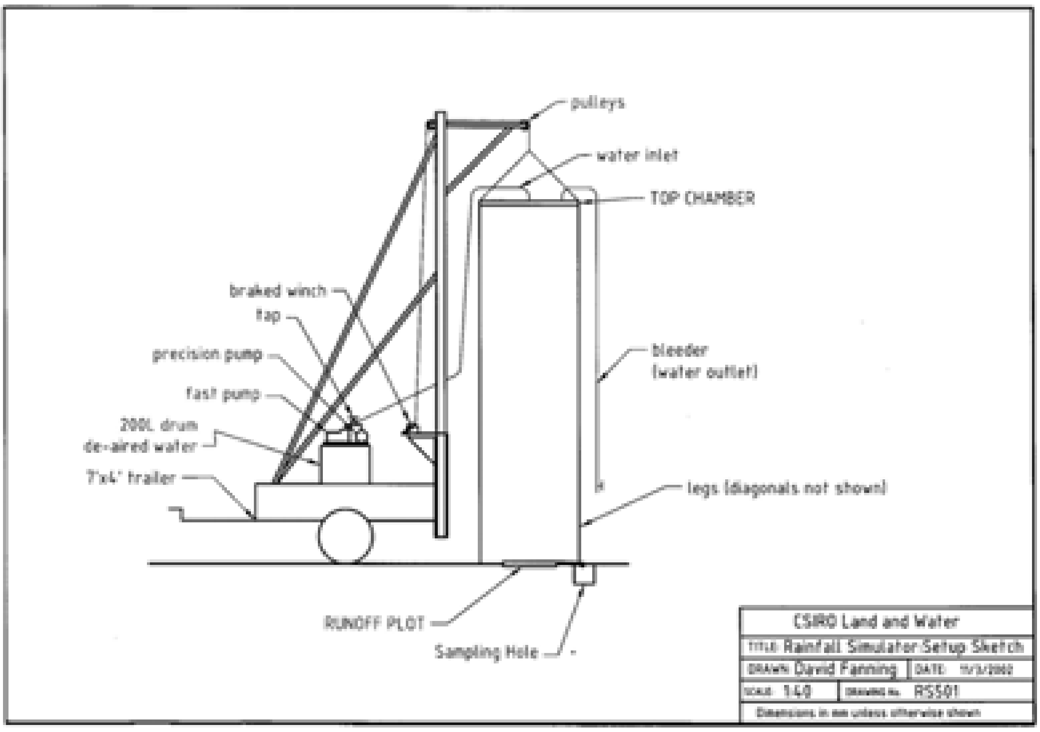


Figure 8.1: Overview sketch of rainfall simulator setup.

Top chamber

The drop-forming unit (Figure 8.2) is an air-tight aluminium chamber (1m x 1m x 0.035 m) with a density of 1300 capillaries/m^2 acting as drop formers. The capillaries are made from single lumen polyethylene tube (OD 1.0 mm x ID 0.50 mm x10 mm long) providing drops of approx. 3.2 mm diameter. The chamber is mounted 4 m above ground on an aluminium frame. It has a water inlet hose, an outlet hose, and a drain tap. The inlet hose supplies/feeds the water while the outlet hose is used to bleed the chamber when filling up.

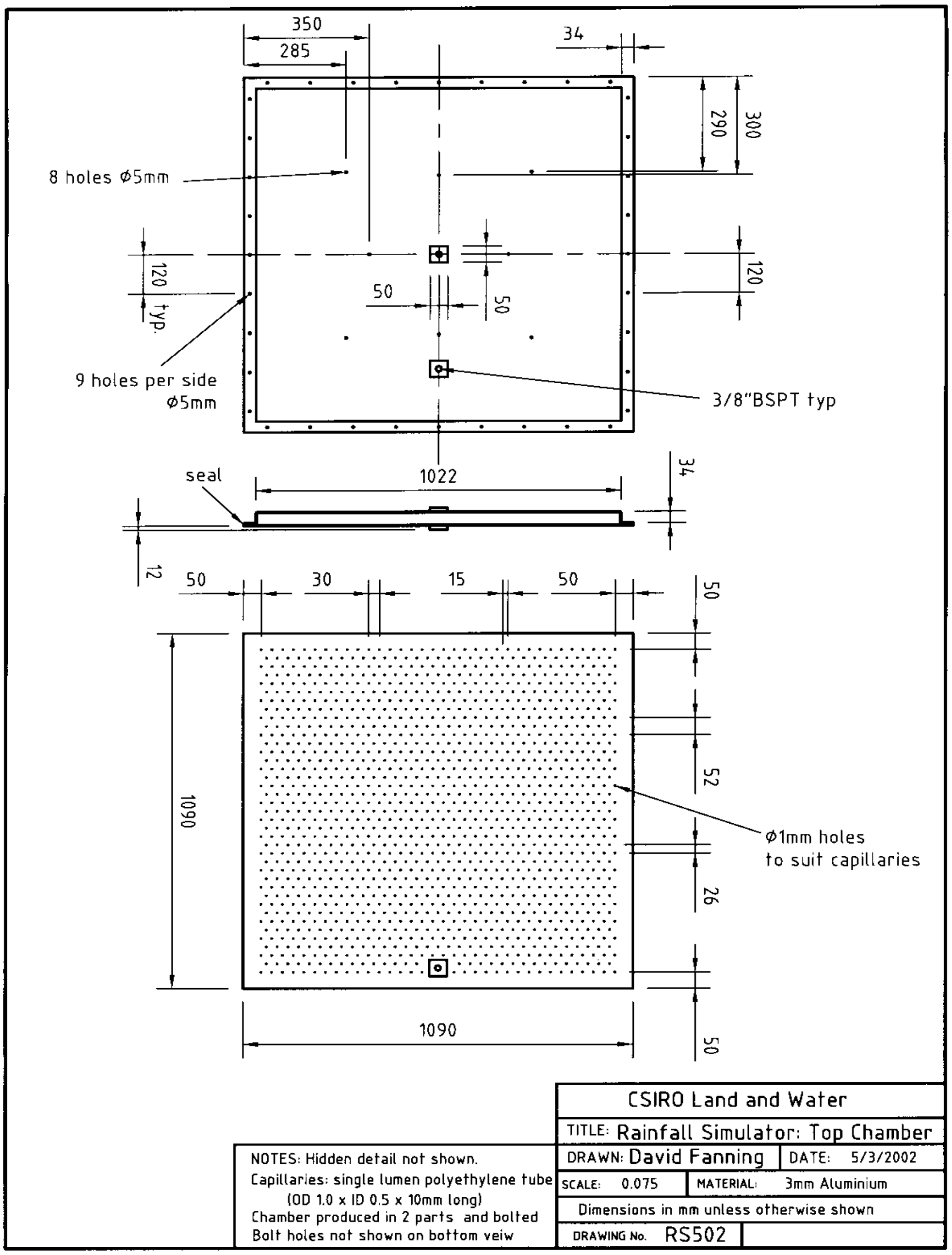


Figure 8.2: Construction details of the top chamber (drop forming unit).

Support frame

For ease of assembly the simulator is broken into three parts: the top frame (supporting the chamber and windshields); the middle leg section (2 m long); and the lower leg section (2 m long). The leg sections include diagonals that maintain rigidity and level operation.

Pumps and water supply

De-aired water is used for the rainfall experiments to minimise clogging of capillaries by air bubbles. The water is stored in three 200 L drums and a single stage vacuum pump is used to de-air the water the day before the experiments is run.

Power to drive the water pumps is supplied from a 2.5 kW generator located away from the experiment site to minimise noise. A fast pump is utilised to fill the drop-forming chamber (0.4 hp; 2800 l/min) until excess waters drains from the outlet. This ensures all the air inside the chamber is forced out. After filling the chamber, the fast pump is stopped and a high precision diaphragm pump with a micrometer control activated that allows for accurate setting of rainfall intensity (Figure 8.3).

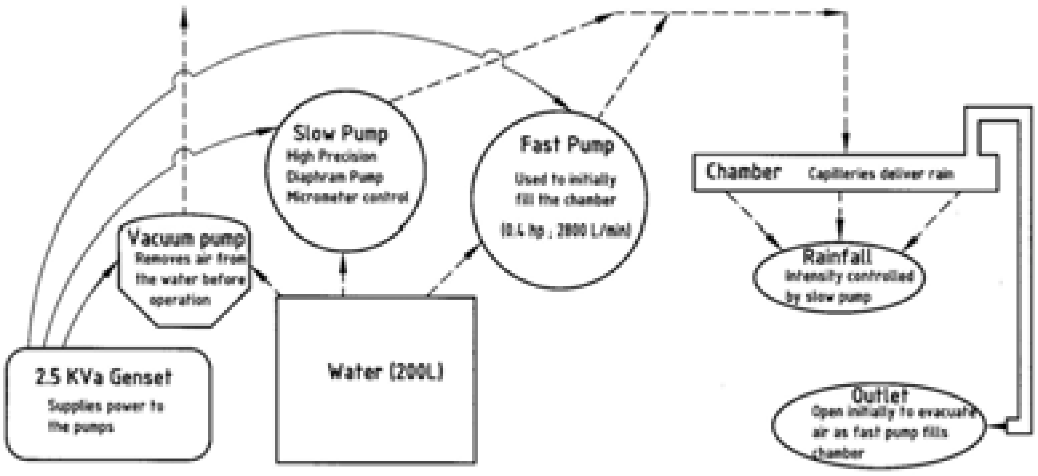


Figure 8.3: Schematic of pump set up.

Runoff plot

The runoff plot is a simple zinc anneal steel frame with a collection area of 0.24 m^2, 600 mm x 400 mm (Figure 8.4). It consists of an open runoff area, a runoff tray that has a clear perspex cover during operation, a drain hole and a front lip.

After the site has been chosen, the sides and bottom of the plot are marked with a spade and a small pit is excavated along the front lip to facilitate sample collection.

There are two methods used for inserting the frame. If the soil is soft enough the plot frames can be tapped directly into the soil. If the soil is very hard, an angle grinder and template need to be used to cut grooves approximately 25 mm deep. The frame is then inserted into these grooves and the edges are sealed by backfilling with loose soil. Careful attention must be given to the front lip of the plot to maintain a good seal with the soil.

It is possible to use preinstalled microplots (of the same surface area; see Appendix 2 in this volume) in the experiments. As there is no installation required, there is little or no disturbance of the soil surface when using these plots.

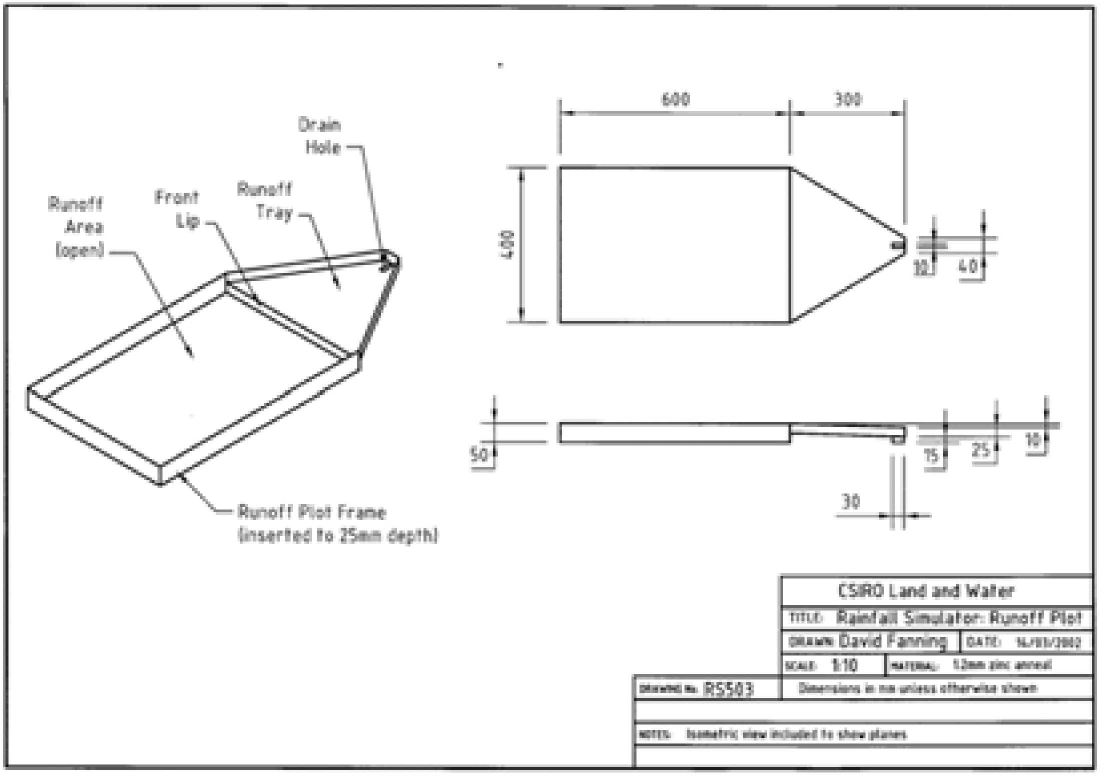


Figure 8.4: Schematic view and dimensions of runoff plot.

Setup

Once experimental sites have been selected the rainfall tower is assembled in the vicinity of the first runoff plot. The top chamber has four multi-stranded cables attached to the four corners for lifting/winching the chamber and the tower into position. Using the trailer mounted 220 kg braked winch and pulley system the chamber is successively lifted and the supports attached. The use of a braked winch is important since the lift can be stopped or lowered at any point with safety.

Once assembled, the entire tower is lifted to at least 20 cm above ground. The trailer is then towed forward, making sure the wheels straddle the plot until the simulator is correctly positioned above the plot. A spirit level is used, and by digging out under the feet and adding packers as necessary the simulator is levelled, ensuring an even distribution of rainfall intensity across the plot area.

To avoid the plot area getting wet before the start of the experiment and to exclude any foreign matter during setup the plot area is covered. To reduce wind effects roll-down vinyl windshields are attached on all four sides of the rainfall tower. These cover 0.1 m under the chamber to 1 m above ground.

Figure 8.5: Views of the rainfall simulator in operation. Wind shield can be lowered in response to main direction of wind.

Experimental procedures

Plot sites were selected to represent the range of soil surface condition found in each landscape. This range was divided into 3-5 classes with 2-3 replicates for each. For example, the range of condition at Meadowvale Station was divided using vegetative cover classes of 'low, medium, high, very high and ungrazed'.

A plastic trough of similar dimension to the runoff plot was used as a rain gauge to check the rainfall intensity over duration of 2 minutes. At least 2 rainfall calibration measurements are necessary, taken at the beginning and at the end of each rainfall run. To start the experiment, the cover over the runoff plot is removed, a clock timer started and a sample-collecting cup placed under the drainage snout.

Runoff samples were collected at 2-minute intervals and samples collected over a cumulative time of 6 minutes were collected into the same sample bottle (1L plastic bottles). The experiments were let to run for 30 minutes at target intensities of 60 mm/hr. At the end of the experiment, a cover was placed over the plot and the final rainfall intensity measured. A 2 cm diameter auger was used to take soil samples for gravimetric water content before and after the rainfall experiments. In some cases, thin clear perspex sheetings were used to trace the plot features such as tussocks to be digitised in the laboratory to determine basal area. The vegetation within the plot was clipped and separated into green litter and dry matter for biomass determination. Core rings of (7.3 cm by 5 cm) were used to take 3 replicate cores for the determination of bulk density from within each runoff plot and to provide soil material for the determination of key nutrients and particle size distribution.

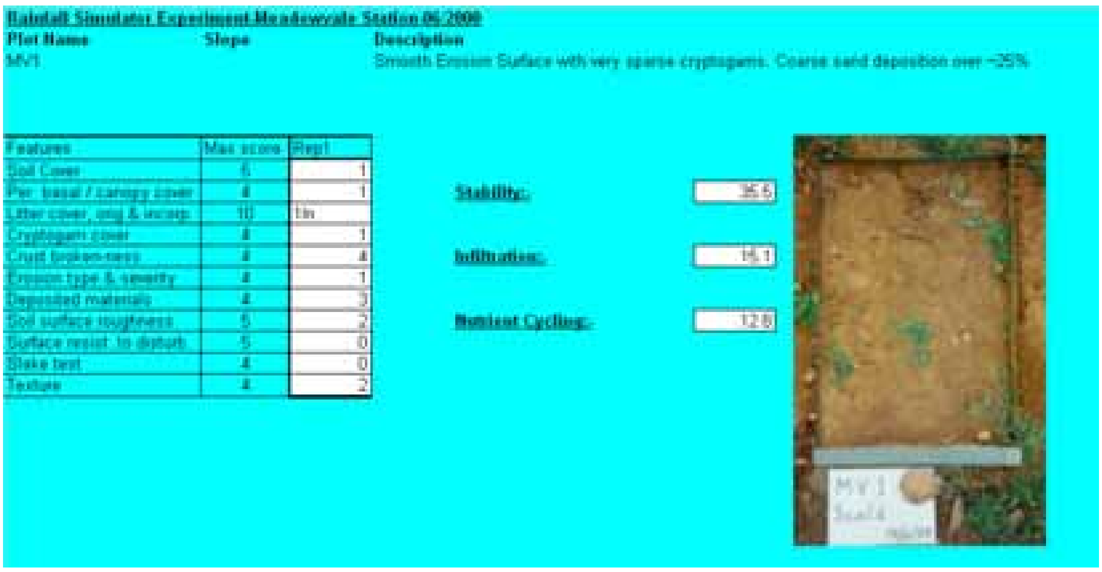
Plot surface description

Apart from the first two experiment sites (Thalanga and Pinnacle Transect), each test plot was photographed and a description of the general characteristics and slope was noted. Soil surface condition of each plot was estimated using a variation of the method proposed by Tongway and Hindley (1995). The procedure was modified to accommodate estimates for area ($0.24m^2$) rather than using the transect method. All of the suggested indicators were used to determine indices for Infiltration (INF), Nutrient Cycling (NUT) and Stability (STAB; see Tongway and Hindley (1995) for more details.

In addition to the Tongway and Hindley indices, all plots were described in terms of soil surface morphological features. These included:

- nature and extent of crusts (loosely following the terminology of Valentin and Bresson, 1992);
- litter, stone/pebble and standing ground cover estimates;
- classes of soil biological activity. These consisted of the following: 1 = low or negligible: no incorporation of litter, no castings, no or little visible soil biological activity; 2 = moderate: 0-50% of litter incorporated into surface; single macrofaunal pores visible; occasional castings; 3 = high: >50% of litter incorporated into surface; <50% of surface covered with castings; enhanced microrelief; 4 = very high: >50% of surface covered with castings; pronounced microrelief; surface uncrusted and friable.

All of the descriptive data collected was then entered into an Excel workbook using the Soil Surface Condition Assessment Trainer (V2 010807) as a template (Tongway and Hindley (2001)). Examples of how the images and the Tongway and Hindley indices were stored are provided in Figure 8.6. Similar data can be obtained from the authors for all microplots in spreadsheet format (except the Thalanga and Pinnacle Transect sites).



Rainfall Simulator Experiment Meadowvale Station 06 2000

Plot Name	Slope	Description
MV1		Smooth Erosion Surface with very sparse cryptogams. Coarse sand deposition over ~25%

Features	Max score	Rep1
Soil Cover	5	1
Per. basal / canopy cover	4	1
Litter cover, orig & incorp.	10	1in
Cryptogam cover	4	1
Crust broken-ness	4	4
Erosion type & severity	4	1
Deposited materials	4	3
Soil surface roughness	5	2
Surface resist. to disturb.	5	0
Slake test	4	0
Texture	4	2

Stability: 35.5

Infiltration: 16.1

Nutrient Cycling: 12.8

Figure 8.6: Example of the format in which plot descriptions and the Tongway & Hindley indices are stored in an Excel spreadsheet.

Field sampling protocols

In overview, the following additional parameters recorded for each runoff plot:

- actual rainfall intensity before and after experiment
- soil moisture before and after (0-5, 5-10, 10-20 cm depth, respectively)
- runoff amount every 2 min approx.
- bulk density 1-5 cm (3 reps)
- particle size distribution 1-5 cm
- total C, N and available P 1-5 cm
- sediment concentration every 10 min approx.
- surface condition assessment using Tongway and Hindley (see preceding section)
- macroscopic morphological description of crusts (extent and crust type - erosional, depositional, structural, cryptogam; see preceding section)
- total percentage cover, split into litter, standing material, cryptogam
- brief soil profile description for each plot (texture, horizons, colour, structure)

For some of the sites we also recorded the following parameters:

- total N and total P in runoff (every 10 min)
- total grass and forb basal area
- particle size distribution 0-1 cm
- total C, N and available P 0-1 cm

Laboratory Analysis

The runoff samples were immediately stored in a cold room (at –18 degrees C) as soon as they were brought in from the field. On completion of the planned experiments, the runoff samples were shaken thoroughly and an aliquot of 125ml taken to be analysed for total N and P (Dissolved and Particulate) as per EPA (1993a, 1993b). The remainder of the sample was left to stand overnight at room temperature. On the second day, the sample was shaken thoroughly and an aliquot analysed for suspended sediment concentrations using the pipette method described by Coventry and Fett (1979).

The bulk density and gravimetric moisture soil samples were immediately weighed and dried at 105^{o}C. The oven-dried bulk density samples were bulked together and a sub-sample used for particle size analysis. The 0 – 1cm soil layer was air-dried and analysed for total nitrogen, total phosphorous and texture. A dehydrator set at 60^{o}C degrees was used to dry the biomass material.

Data Analysis

All the data were stored and analysed in Excel spreadsheets.

(i) Concentration total suspended sediment
Concentration of total suspended sediment (g/L) = Weight of suspended sediment in aliquot (g) * 1000/Volume of aliquot ml) Eq. 1

(ii) Calculation of rainfall intensity
The rainfall intensity over the complete run was assumed to scale gradually from the initial to the final measured intensity:

Scaled rainfall intensity (mm/hr) = [Volume of water (ml) collected in time t (min)* 60] /[(time t (min) * Cross sectional area of rain gauge (cm^2)]*10. Eq. 2

(iii) Calculation of infiltration rate
The collected runoff was converted to runoff rate:

Runoff rate (mm/hr) = [Volume of runoff (ml) in time t (min) *60 min]/[time t (min) * plot area (cm^2)] * 10 Eq. 3

Hence, the infiltration rate at a particular time (t) is:

Infiltration rate (mm/hr) = [Scaled rainfall intensity (mm/hr) – Runoff rate (mm/hr)] Eq. 4

Infiltration rate was then plotted as a function of time (see Figure 8.7) and also total rainfall. The latter procedure allowed the determination of a normalised infiltration index I_{30} (infiltration rate at 30 mm rainfall depth). In both cases, the data were fitted to a modified Horton equation using Excel SOLVER:

Instantaneous infiltration rate (mm/hr) = a * exp [b * time (min)] + I_f (mm/hr) Eq. 5

Alternatively

Instantaneous infiltration rate (mm/hr) = A * exp [B * rainfall depth (mm)] + I_f (mm/hr) Eq. 6

Where a, b A and B are fitting parameters, and I_f is final infiltration rate.

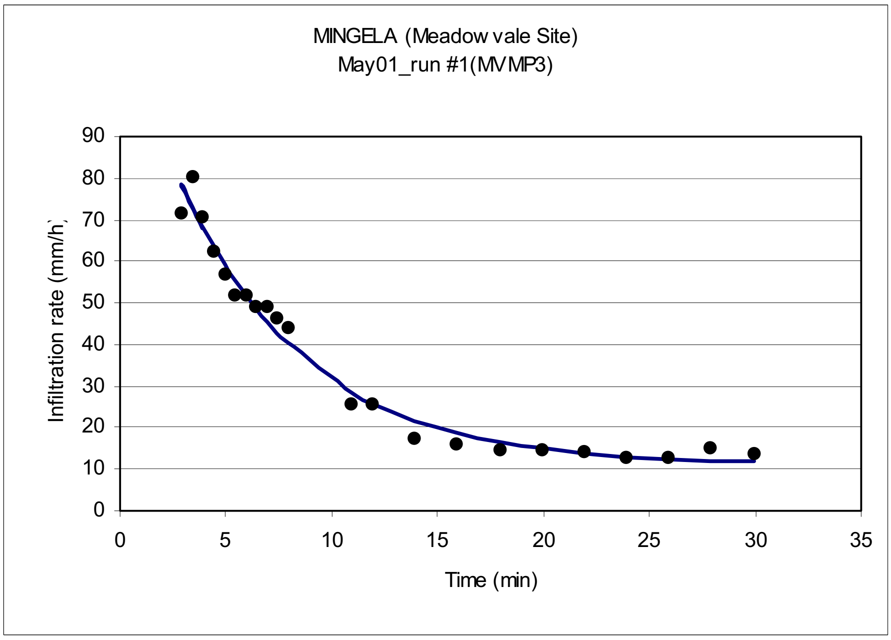


Figure 8.7: Example of measured infiltration rates derived using Equation 4 plotted against time and fitted using Equation 5.

Site descriptions
Site 1: Thalanga

General description:
A. Noble's Stylo monitoring site (NAP project 3.218) paired site with native pasture (moderately to heavily grazed, plots 1-6) and a Stylo dominant pasture (plots 7-9), in which all trees had died off; paired sites about 50m apart. Ground cover very patchy; general condition of both paired sites moderate to poor.

Site code:	TH
Date Studied:	July 1998
Dominant trees:	Silver-leafed Ironbark (*Eucalyptus melanophloia*)
Dominant grasses:	Wiregrass *(Aristida spp.)* Stylo *(Stylosanthes spp.)*
Hillslope position:	Upper slope
General slope:	0-3%
Geology:	Cainozoic sediments
Soil type:	Yellow Kandosol (Boston series)
Longitude: **Latitude:**	E145°47'38.27" S20°21'57.91"

Site 2: Pinnacle Transect, TFTA

General description:
Site on Dotswood military training area; heavily degraded, grazed site with signs of initial recovery (State II/III; plots 1-12); ground cover patchy with large scalds interspersed; some military vehicle activity (APC swerve tracks; plots 13-15).

Site code: PT
Date Studied: November 1998

Dominant trees: Narrow-leafed Ironbark (*Eucalyptus crebra*)

Dominant grasses: Desert Bluegrass *(Bothriochloa ewartiana)* Wiregrass *(Aristida spp.)*

Hillslope position: Mid-slope

General slope: 3-7%

Geology: Devonian sediments Sedimentary rocks

Soil type: Red Chromosol (Ceasar series) Brown/Yellow Chromosol (Greenvale series)

Longitude: E146°19'40.66"
Latitude: S19°32'42.71"

Site 3: Simpson's Dam, TFTA

General description:
Site on Dotswood military training area; heavily degraded, grazed site with signs of recovery (more pronounced than site 1 as cattle already removed, State II); ground cover patchy, with some large gravel covered scalds. No military activity.

Site code:	SD
Date Studied:	April 1999
Dominant trees:	Reid River Box (*Eucalyptus brownii)*
Dominant grasses:	Desert Bluegrass (*Bothriochloa ewartiana)* Golden Beard Grass *(Chrysopogon fallax)* Hairy Panic *(Panicum effusum)*
Hillslope position:	Upper to mid-slope
General slope:	1-3%
Geology:	Metamorphic rocks Metasediments
Soil type:	Red Chromosol (Rangeview series) Brown/Yellow Sodosol (Warrawee series)
Longitude: **Latitude:**	E146°13'41.87" S19°27'22.47"

Site 4: High Range, TFTA

General description:
Site on Dotswood military training area (TFTA section); site with no grazing over the past 20 years; general site condition excellent, except permanent tracks from APC's; high level APC activity; one section of site burned (plots 1-10); plots 11-14 unburnt.

Site code: HR

Date Studied: November 1999

Dominant trees: Narrow-leafed Ironbark
(*Eucalyptus crebra*)

Dominant grasses: Kangaroo grass
(Themeda triandra)
Black Speargrass
(Heteropogon contortus)

Hillslope position: Mid-slope

General slope: 3-7%

Geology: Granite/Granodiorite

Soil type: Brown Chromosol
(Bluff series)
Yellow Chromosol
(Bluff series)

Longitude: E146°26'33.42"
Latitude: S19°27'58.07"

Site 5: Meadowvale

General description:
Main NAP 3.224 erosion monitoring site (microplots; hillslope runoff plots, stream gauging); history of heavy stocking and overall condition poor (State III/IV), with loss of perennial grasses replaced by *Bothriochloa pertusa*; 500 m from monitoring site one of Pressland/Scanlan exclosure sites; plots 9B-12B on grazing exclosure, that now has some grazing. Two series: series A in 2000 and series B in 2001, including some of the permanent microplots.

Site code:	MNA and MNB
Date Studied:	June 2000 (A); May 2001 (B)
Dominant trees:	Narrow-leafed Ironbark (*Eucalyptus crebra*)
Dominant grasses:	Indian couch *(Bothriochloa pertusa)*
Hillslope position:	Upper to mid-slope
General slope:	5-8%
Geology:	Granodiorite
Soil type:	Red Chromosol (Dalrymple series) (eroded phase)
Longitude: **Latitude:**	E146°35'19.81" S19°50'30.67"

Site 6: Wambiana

General description: Paddock 1 in DPI Wambiana grazing trial; fairly heavily stocked over the last 5 years; good cover of perennials; some patches with less desirable species; clumps of Carissa (~25% of area) ungrazed for many years; general site condition moderate.

Site code: WB

Date Studied: May 2002

Dominant trees: Reid River Box
(*Eucalyptus brownii*)
Current bush
(*Carissa ovata*)

Dominant grasses: Golden Beard Grass
(*Chrysopogon fallax*)
Wiregrass
(*Aristida spp.*)
Desert Bluegrass
(*Bothriochloa ewartiana*)

Hillslope position: Mid-slope

General slope: 0-2%

Geology: Cainozoic Sediments

Soil type: Brown-grey Sodosol
(Liontown series)

Longitude: E146°07'02.62"
Latitude: S20°33'19.42"

Individual plot infiltration and sediment concentration data on a site-by-site basis

Thalanga TH1

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.0	57.6	6.0	4.7
4.0	42.0	10.0	4.8
6.0	18.3	14.0	4.1
8.0	4.6	18.0	3.7
10.0	4.6	22.0	3.5
12.0	7.1	26.0	4.0
14.0	5.3	30.0	2.9
16.0	4.7		
18.0	3.5		
20.0	4.0		
22.0	6.1		
24.0	4.2		
26.0	4.3		
28.0	3.7		
30.0	9.3		

Thalanga TH2

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
5.8	39.9	9.0	1.884
6.5	14.7	11.5	1.316
7.9	18.4	14.0	1.452
9.1	10.7	17.0	1.488
10.3	8.3	20.0	0.856
11.4	9.8	24.0	0.800
12.6	9.9	30.0	0.660
13.8	11.3		
14.9	8.9		
16.0	7.6		
17.1	7.8		
18.2	6.4		
19.2	3.3		
20.3	8.1		
21.4	8.2		
22.5	9.7		
23.6	8.5		
24.8	10.0		
25.8	7.3		
26.9	8.9		
28.1	10.4		
29.1	7.7		
30.0	14.8		

Thalanga TH3

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.6	40.5	6.0	0.852
3.7	43.5	11.0	0.580
4.5	29.3	16.0	0.496
5.9	23.6	21.0	0.332
7.2	19.9	26.0	0.276
8.9	16.1	30.0	0.252
10.1	17.9		
11.3	16.8		
12.5	18.1		
13.7	18.2		
14.9	19.5		
16.1	18.5		
17.3	18.6		
18.5	18.7		
19.7	17.6		
20.8	16.4		
22.0	17.8		
23.1	17.9		
24.3	18.1		
25.4	16.9		
26.6	18.3		
27.7	15.7		
28.8	17.2		

Thalanga TH7

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
10.9	60.5	6.0	1.448
11.4	46.4	12.0	1.068
12.4	44.6	18.0	0.924
13.7	42.1	24.0	0.720
14.5	40.6	30.0	0.636
16.1	39.8		
18.3	39.5		
20.3	37.1		
22.2	35.9		
24.0	34.1		
25.6	32.0		
27.2	32.2		
28.9	33.0		
30.0	33.8		

Thalanga TH8

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
3.1	51.6	6.0	1.236
4.6	52.7	12.0	1.056
6.3	49.0	17.0	0.844
8.3	47.5	22.0	0.784
9.7	42.3	26.0	0.728
12.3	40.9	30.0	0.720
15.9	40.2		
19.4	40.2		
22.9	40.3		
26.5	41.0		
30.9	43.9		

Thalanga TH9

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
4.7	60.3	8.0	2.364
5.5	42.0	12.0	1.368
6.6	35.0	16.0	0.824
8.5	27.7	20.0	0.944
10.5	29.8	24.0	0.696
11.8	25.5	30.0	0.612
13.1	23.4		
15.1	20.2		
15.9	20.8		
16.9	22.0		
17.9	20.6		
19.0	25.3		
20.1	22.9		
21.2	25.1		
22.3	22.6		
23.4	23.7		
24.5	23.5		
25.6	23.4		
26.7	23.3		
27.8	23.1		
29.0	27.1		
30.0	26.2		

Pinnacle transect PT1

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
1.5	41.5	6.0	6.300
2.0	5.7	12.0	3.836
3.0	18.3	18.0	3.264
4.0	14.6	24.0	2.956
6.0	19.2	30.0	3.200
8.0	15.6		
10.0	13.8		
12.0	12.7		
14.0	17.9		
16.0	17.4		
18.0	22.5		
20.0	16.4		
22.0	16.6		
24.0	17.4		
26.0	16.3		
28.0	18.3		
30.0	15.3		

Pinnacle transect PT2

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
3.5	51.3	6.0	3.880
4.0	41.6	12.0	2.004
5.0	32.8	18.0	1.528
5.3	14.9	24.0	1.420
6.0	33.2	30.0	1.500
8.0	22.5		
10.0	16.7		
12.0	14.0		
14.0	11.4		
16.0	11.8		
18.0	10.4		
20.0	10.2		
22.0	8.8		
24.0	8.0		
26.0	6.5		
28.0	4.5		
30.0	4.9		

Pinnacle transect PT3

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
6.0	57.8	6.0	
8.0	30.8	12.0	1.704
10.0	24.6	18.0	1.124
12.0	20.3	24.0	0.728
14.0	18.6	30.0	0.712
16.0	19.3		
18.0	16.9		
20.0	17.0		
22.0	16.4		
24.0	15.3		
26.0	14.7		
28.0	14.8		
30.0	12.4		

Pinnacle transect PT4

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
5.5	52.9	12.0	1.216
6.5	30.4	18.0	0.704
7.0	28.0	24.0	0.608
8.0	23.1	30.0	0.508
9.0	22.1		
12.0	20.5		
14.0	18.5		
16.0	22.0		
18.0	20.5		
20.0	15.8		
22.0	17.4		
24.0	16.5		
26.0	16.9		
28.0	17.8		
30.0	16.9		

Pinnacle transect PT5

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
10.0	56.5	12.0	
11.0	41.6	17.0	0.684
12.0	37.5	23.0	0.420
13.0	37.2	29.0	0.340
15.0	35.3	35.0	0.320
17.0	29.6	41.0	0.260
19.0	25.8		
21.0	23.9		
23.0	23.3		
25.0	21.4		
27.0	24.5		
29.0	24.4		
31.0	26.9		
33.0	23.1		
35.0	26.8		
37.0	23.7		
39.0	22.4		
41.0	21.7		

Pinnacle transect PT6

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
3.0	49.5	6.0	2.884
3.5	22.1	12.0	2.064
4.0	17.2	18.0	1.528
4.5	17.3	24.0	1.536
5.0	7.4	30.0	1.416
5.5	12.5		
6.0	12.5		
6.5	5.1		
7.0	5.2		
7.5	7.8		
8.0	5.4		
8.5	5.4		
9.0	5.5		
9.5	10.6		
10.0	8.2		
10.5	3.3		
11.0	13.4		
11.5	3.4		
13.0	19.5		
14.0	8.8		
15.0	5.3		
16.0	5.4		
18.0	7.0		
20.0	7.3		
22.0	10.2		
24.0	5.5		
26.0	8.3		
28.0	5.5		
30.0	7.1		

Pinnacle transect PT7

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
4.0	59.2	6.0	1.632
4.5	7.3	12.0	1.036
5.5	8.4	18.0	0.692
6.0	9.6	24.0	0.656
7.0	13.2	30.0	0.468
8.0	11.8		
9.0	9.1		
10.0	10.3		
11.0	10.1		
12.0	8.7		
14.0	10.3		
16.0	5.0		
18.0	6.6		
20.0	6.9		
22.0	7.3		
24.0	7.0		
26.0	6.7		
28.0	8.3		
30.0	8.6		

Pinnacle transect PT8

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.0	44.6	6.0	6.048
2.5	16.0	12.0	3.880
3.0	26.0	18.0	3.320
3.5	16.1	24.0	3.180
4.0	13.7	30.0	3.136
4.5	13.8	36.0	3.520
5.0	18.9		
5.5	14.0		
6.0	14.1		
8.0	15.0		
10.0	13.5		
12.0	13.8		
14.0	14.2		
16.0	14.5		
18.0	15.5		
20.2	19.2		
22.0	13.6		
24.0	14.0		
26.0	12.5		
28.2	15.9		
30.0	17.7		
32.0	14.1		
34.0	13.8		
36.0	13.5		

Pinnacle transect PT9

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
3.5	56.8	6.0	
4.5	48.4	12.0	1.068
5.0	44.6	18.0	0.632
5.5	42.1	24.0	0.452
6.0	39.6	30.0	0.384
6.5	34.5		
7.0	29.5		
7.5	24.5		
8.0	24.5		
10.0	20.1		
12.0	12.5		
14.0	12.4		
16.0	11.1		
18.0	11.7		
20.0	11.0		
22.0	11.6		
24.0	10.9		
26.7	9.1		
28.3	9.9		
30.0	9.1		
32.0	9.4		

Pinnacle transect PT10

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
3.5	62.8	6.0	
4.0	58.0	12.0	0.608
4.5	52.9	18.0	0.848
5.0	52.8	24.0	0.404
5.5	50.2	30.0	0.316
6.0	45.2		
6.5	40.1		
7.0	37.5		
7.5	32.4		
8.0	29.8		
10.0	28.2		
12.0	25.3		
14.0	24.9		
16.3	27.0		
18.0	23.7		
20.0	22.6		
22.0	21.0		
24.0	22.5		
26.0	22.7		
28.0	20.5		
30.0	20.1		

Pinnacle transect PT11

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
8.0	53.1	12.0	0.780
8.5	51.0	18.0	0.440
9.0	48.4	24.0	0.360
9.5	43.3	30.0	0.272
10.0	40.7		
11.0	33.1		
12.0	29.1		
14.0	29.4		
16.0	27.9		
18.0	26.3		
20.0	22.8		
22.0	21.2		
24.0	21.5		
26.0	18.7		
28.3	18.5		
30.0	13.9		

Pinnacle transect PT12

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
5.5	61.0	12.0	0.432
6.0	56.2	18.0	0.252
6.5	43.7	24.0	0.208
7.0	36.2	30.0	0.176
7.5	28.7		
8.0	26.2		
8.5	23.7		
9.0	23.7		
9.5	21.2		
10.0	21.2		
12.0	21.8		
14.0	18.7		
16.0	12.4		
18.0	11.8		
20.0	16.8		
22.0	16.2		
24.0	17.4		
26.0	14.9		
28.0	18.1		
30.0	16.8		

Pinnacle transect
PT13

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
0.5	36.9	6.0	1.536
1.0	31.9	12.0	1.224
1.5	24.5	18.0	1.052
2.0	22.0	24.0	0.936
2.5	17.0	30.0	0.960
3.0	14.5		
3.5	12.1		
4.0	9.6		
4.5	7.1		
5.0	7.1		
5.5	4.7		
6.0	4.7		
8.0	9.8		
10.0	4.9		
12.0	6.2		
14.0	3.8		
16.0	8.3		
18.0	5.9		
20.0	7.2		
22.0	6.1		
24.0	5.5		
26.0	5.6		
28.0	5.7		
30.0	8.9		

Pinnacle transect
PT14

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
3.5	51.8	6.0	1.788
4.0	28.9	12.0	1.212
4.5	23.9	18.0	1.140
5.0	16.4	24.0	1.068
5.5	13.9	30.0	1.020
6.0	11.4		
6.5	11.3		
7.0	11.3		
7.5	11.3		
8.0	11.3		
10.0	12.5		
12.0	12.4		
14.0	13.0		
16.0	11.7		
18.0	16.0		
20.0	14.0		
22.0	10.2		
24.0	8.3		
26.0	9.5		
28.0	7.5		
30.0	4.9		

Pinnacle transect
PT15

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.5	48.8	6.0	4.156
3.0	28.7	14.0	2.624
3.5	18.7	18.0	2.904
4.0	13.6	24.0	2.676
4.5	13.5	30.0	2.304
5.0	13.5		
5.5	10.9		
6.0	15.9		
8.0	12.5		
10.0	14.8		
12.0	10.2		
14.0	11.2		
16.0	12.3		
18.0	12.7		
20.0	10.6		
22.0	12.2		
24.0	12.0		
26.0	8.0		
28.0	8.4		
30.0	11.3		

Simpson's dam
SD1

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
1.7	56.3	7.7	1.900
2.2	40.0	12.0	1.172
2.7	35.8	16.0	0.964
3.2	30.1	22.0	0.796
3.7	29.1	26.0	0.784
4.2	25.5	30.0	0.732
4.7	29.4	34.0	0.768
5.2	31.0		
5.7	28.1		
6.2	25.5		
6.7	30.4		
7.2	30.8		
7.7	32.7		
8.9	31.0		
10.0	33.5		
11.0	32.7		
12.0	30.3		
13.0	27.8		
14.0	27.8		
16.0	28.5		
18.0	31.9		
20.0	30.4		
22.0	31.1		
24.1	26.3		
26.0	22.2		
28.0	20.6		
30.0	20.6		
32.0	20.4		
34.0	19.8		

Simpson's dam
SD2

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.8	56.4	8.2	1.844
3.2	45.9	12.2	1.192
3.7	41.9	16.2	0.924
4.2	38.4	20.2	0.808
4.7	33.9	24.2	0.732
5.2	28.9	28.2	0.688
5.7	27.9	30.2	0.612
6.2	27.4		
6.7	23.9		
7.2	21.7		
7.7	20.9		
8.2	16.9		
9.2	17.9		
10.2	16.6		
11.2	12.9		
12.2	15.4		
14.2	14.1		
16.2	12.9		
18.2	10.4		
20.2	11.0		
22.2	10.1		
24.2	9.3		
26.2	9.1		
28.2	10.4		
30.2	10.4		

Simpson's dam
SD3

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
3.7	56.1	9.2	0.504
4.2	46.9	14.2	0.336
4.7	39.0	20.2	0.276
5.2	33.0	24.2	0.248
5.7	32.0	28.2	0.228
6.2	30.6	32.2	0.232
6.7	26.2		
7.2	24.7		
7.7	23.3		
8.2	25.8		
8.7	24.9		
9.2	25.4		
10.2	22.6		
11.2	23.9		
12.2	24.0		
13.2	22.9		
14.2	23.0		
16.2	23.9		
18.2	26.0		
20.2	25.6		
22.2	27.1		
24.2	29.2		
26.2	26.3		
28.2	27.1		
30.2	27.3		
32.2	27.6		

Simpson's dam
SD4

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
3.1	60.0	5.6	0.664
3.6	33.4	9.1	0.484
4.1	25.8	14.1	0.384
4.6	25.8	18.0	0.320
5.1	20.3	24.0	0.284
5.6	18.8	30.0	0.276
6.1	19.8		
7.1	16.0		
8.1	17.2		
9.1	16.4		
10.1	16.4		
12.1	14.8		
14.1	15.1		
16.0	13.6		
18.0	12.4		
20.0	12.3		
22.0	13.5		
24.0	10.9		
26.0	10.2		
28.0	11.4		
30.0	10.7		

Simpson's dam
SD5

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.0	51.0	8.0	0.548
2.5	45.7	12.0	0.376
3.0	45.8	18.0	0.316
3.5	37.0	24.0	0.324
4.0	35.5	30.0	0.268
4.5	35.5		
5.0	32.0		
5.5	27.0		
6.0	24.5		
6.6	25.7		
7.0	24.3		
8.0	23.3		
9.0	24.6		
10.0	23.3		
12.0	22.6		
14.2	24.4		
16.0	22.4		
18.0	23.4		
20.0	22.2		
22.0	23.5		
24.0	22.9		
26.0	23.5		
28.0	24.2		
30.0	25.5		

Simpson's dam
SD6

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.3	61.6	8.2	0.592
2.8	59.1	12.2	0.348
3.2	57.6	16.2	0.296
3.7	53.2	20.2	0.248
4.2	45.2	26.2	0.208
4.7	44.2	30.2	0.184
5.2	42.3		
5.7	42.3		
6.2	37.3		
6.7	34.9		
7.2	37.4		
8.2	35.0		
9.2	33.5		
10.2	32.6		
11.2	32.7		
12.2	32.7		
14.2	32.9		
16.2	33.6		
18.2	33.1		
20.2	32.6		
22.2	32.1		
24.2	36.0		
26.2	31.1		
28.2	31.3		
30.2	30.8		

Simpson's dam
SD7

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.8	56.0	6.3	1.128
3.3	26.1	10.3	0.704
3.8	21.6	14.3	0.580
4.3	15.6	18.3	0.488
4.8	15.6	24.3	0.428
5.3	11.6	30.3	0.376
5.8	8.6		
6.3	13.7		
7.3	9.4		
8.3	9.7		
9.3	10.8		
10.3	9.8		
12.3	9.2		
14.3	9.9		
16.3	10.0		
18.3	10.1		
20.3	8.9		
22.3	9.6		
24.3	9.6		
26.3	10.3		
28.3	8.5		
30.3	9.2		

Simpson's dam
SD8

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
1.6	56.4	6.1	2.888
2.1	27.8	12.1	2.092
2.6	19.3	18.1	1.804
3.1	22.8	24.1	1.728
3.6	12.9	30.2	1.712
4.1	15.4		
4.6	13.9		
5.1	11.4		
5.6	17.9		
6.1	10.4		
8.1	13.6		
10.1	11.1		
12.1	11.8		
14.1	12.4		
16.1	12.4		
18.1	12.5		
20.1	10.0		
22.1	11.9		
24.1	10.7		
26.1	10.1		
28.1	8.3		
30.1	7.1		

Simpson's dam
SD9

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
1.5	55.6	5.5	3.076
2.0	36.0	10.5	2.432
2.5	29.5	16.5	2.272
3.0	21.0	24.5	2.200
3.5	16.5	30.5	1.896
4.0	15.1		
4.5	15.6		
5.0	14.1		
5.5	12.6		
6.5	10.3		
7.5	14.1		
8.5	11.3		
9.5	10.1		
10.5	8.6		
12.5	11.1		
14.5	10.5		
16.5	13.0		
18.5	11.1		
20.5	11.2		
22.5	9.9		
24.5	12.4		
26.5	13.1		
28.5	11.8		
30.5	11.8		

Simpson's dam SD10

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
8.6	53.0	15.6	0.320
9.1	42.4	20.6	0.216
9.6	45.9	26.6	0.184
10.1	41.4	32.6	0.172
10.6	40.9		
11.1	38.9		
11.6	37.9		
12.6	36.4		
13.6	34.8		
14.6	32.6		
15.6	33.8		
16.6	33.8		
18.6	32.8		
20.6	32.6		
22.6	29.5		
24.6	29.1		
26.6	28.3		
28.6	28.2		
30.6	28.2		
32.6	27.3		

Simpson's dam SD12

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
3.5	52.7	10.0	0.600
4.0	44.5	16.0	0.360
4.5	42.9	22.0	0.284
5.0	39.9	28.0	0.256
5.5	37.3	32.0	0.212
6.0	35.7		
6.5	33.1		
7.0	30.5		
7.5	29.4		
8.0	27.9		
9.0	26.9		
10.0	26.0		
12.0	21.6		
14.0	19.4		
16.0	19.0		
18.0	18.7		
20.0	18.4		
22.0	18.3		
24.0	16.5		
26.0	14.9		
28.0	15.8		
30.0	16.1		
32.0	15.1		

Simpson's dam SD13

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
3.3	56.8	7.8	0.972
3.8	43.5	13.8	0.764
4.3	35.9	19.8	0.688
4.8	34.4	23.8	0.588
5.3	33.3	27.8	0.540
5.8	33.8	31.8	0.528
6.3	32.2		
6.8	29.7		
7.8	25.9		
9.8	23.8		
11.8	20.9		
13.8	21.3		
15.8	19.5		
17.8	20.0		
19.8	18.9		
21.8	18.1		
23.8	17.5		
25.8	17.0		
27.8	16.6		
29.8	14.4		
31.8	14.1		

High Range (TFTA) HR1

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
3.5	58.2	12.0	1.376
4.0	57.0	18.0	1.008
4.5	57.1	24.0	0.832
5.0	54.6	30.0	0.600
5.5	48.1		
6.0	43.1		
6.5	40.6		
7.0	40.1		
7.5	38.1		
8.0	38.1		
9.0	37.4		
10.0	37.4		
11.0	35.4		
12.0	32.4		
14.0	33.7		
16.0	31.2		
18.0	29.4		
20.0	30.1		
22.0	30.7		
24.0	32.0		
26.0	30.2		
28.0	30.8		
30.0	27.1		

High Range (TFTA) HR2

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
3.0	64.3	12.0	2.308
3.5	56.6	18.0	1.888
4.0	50.5	24.0	1.580
4.5	46.3	30.0	1.600
5.0	40.6		
5.5	37.4		
6.0	34.8		
6.5	32.1		
7.0	34.9		
7.5	34.8		
10.0	37.9		
12.0	26.6		
14.0	28.4		
16.0	27.1		
18.0	28.9		
20.0	25.7		
22.0	25.0		
24.0	28.1		
26.0	24.3		
28.0	23.6		
30.0	22.9		

High Range (TFTA) HR3

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.0	62.4	6.0	1.708
2.5	37.2	12.0	1.084
3.0	28.8	18.0	0.940
3.5	16.3	24.0	1.216
4.0	18.8	30.0	0.784
4.5	18.9		
5.0	21.4		
6.0	17.7		
7.0	6.6		
8.0	10.4		
9.0	10.5		
10.0	13.0		
12.0	21.3		
14.0	7.1		
16.0	9.7		
18.0	7.4		
20.0	12.5		
22.0	12.7		
24.0	12.8		
26.0	11.7		
28.0	9.4		
30.0	14.5		

High Range (TFTA)
HR4

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.5	54.5	6.0	1.632
3.0	26.4	12.0	1.160
3.5	20.9	18.0	0.956
4.0	21.4	24.0	0.932
4.5	20.4	30.0	0.868
5.0	18.3		
5.5	16.3		
6.0	16.8		
7.0	14.8		
8.0	19.7		
9.0	18.5		
10.0	18.9		
11.0	17.9		
12.0	16.9		
14.0	18.5		
16.0	17.2		
18.0	20.0		
20.0	17.6		
22.0	17.0		
24.0	19.0		
26.0	17.3		
28.0	17.6		
30.0	17.0		

High Range (TFTA)
HR5

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.5	60.2	6.0	1.628
3.0	50.8	12.0	1.340
3.5	46.2	18.0	1.308
4.0	41.7	24.0	1.168
4.5	39.7	30.0	1.028
5.0	35.2		
5.5	31.2		
6.0	33.6		
7.0	31.3		
8.0	29.8		
9.0	31.0		
10.0	29.7		
11.0	29.4		
12.0	28.6		
14.0	28.8		
16.0	29.2		
18.0	27.9		
20.0	29.6		
22.0	30.4		
24.0	28.3		
26.0	29.9		
28.0	27.3		
30.0	26.9		

High Range (TFTA)
HR6

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.5	72.7	6.0	1.592
3.0	65.7	12.0	1.336
3.5	63.6	18.0	1.080
4.0	59.6	24.0	0.976
4.5	54.6	30.0	0.880
5.0	51.1		
5.5	47.0		
6.0	48.0		
7.0	44.9		
8.0	44.1		
9.0	42.3		
10.0	44.5		
11.0	44.9		
12.0	40.6		
14.0	45.6		
16.0	43.9		
18.0	41.8		
20.0	45.0		
22.0	43.5		
24.0	42.9		
26.0	40.6		
28.0	41.6		
30.0	42.1		

High Range (TFTA)
HR7

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
3.5	63.8	6.0	1.088
4.0	52.0	12.0	0.812
4.5	51.1	18.0	0.580
5.0	49.1	24.0	0.576
5.5	47.6	30.0	0.412
6.0	47.7		
7.0	50.3		
8.0	53.4		
9.0	53.5		
10.0	54.1		
11.0	54.4		
12.0	53.7		
14.0	56.0		
16.0	56.8		
18.0	57.0		
20.0	57.1		
22.0	57.8		
24.0	57.5		
26.0	59.6		
28.0	59.4		
30.0	59.4		

High Range (TFTA)
HR8

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.5	72.8	6.0	1.340
3.0	69.8	12.0	0.944
3.5	65.8	18.0	0.856
4.0	62.8	24.0	0.784
4.5	56.4	30.0	0.872
5.0	51.4		
5.5	45.0		
6.0	50.5		
7.0	47.9		
8.0	39.7		
9.0	39.3		
10.0	35.4		
11.0	41.5		
12.0	39.1		
14.0	40.8		
16.0	39.5		
18.0	37.2		
20.0	37.3		
22.0	35.0		
24.0	35.5		
26.0	40.2		
28.0	43.1		
30.0	22.4		

High Range (TFTA)
HR9

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.0	72.8	12.0	1.184
4.0	70.1	22.0	0.996
6.0	70.1	30.0	0.820
8.0	70.0		
10.0	69.8		
12.0	70.5		
14.0	70.1		
16.0	68.2		
18.0	68.7		
20.0	68.3		
22.0	68.1		
24.0	68.0		
26.0	67.8		
28.0	67.0		
30.0	66.5		

High Range (TFTA)				High Range (TFTA)				High Range (TFTA)			
HR10				HR12				HR13			
time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)	time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)	time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.0	69.3	6.0	1.388	2.5	87.7	8.0	0.344	4.5	64.2	12.0	0.520
2.5	58.5	12.0	1.248	3.0	71.1	16.0	0.256	5.0	57.6	18.0	0.344
3.0	55.7	18.0	0.888	4.0	73.6	24.0	0.148	5.5	55.5	24.0	0.336
3.5	49.3	24.0	0.844	5.0	72.3	32.0	0.116	6.0	56.0	34.0	0.284
4.0	44.5	30.0	0.852	6.0	72.3			6.5	54.4		
4.5	42.2			7.0	71.8			7.0	54.3		
5.0	40.9			8.0	71.5			8.0	52.2		
5.5	40.0			9.0	70.7			9.0	52.1		
6.0	37.7			10.0	73.2			10.0	51.8		
7.0	37.6			12.0	79.6			12.0	49.3		
8.0	33.4			14.0	76.3			14.0	47.8		
9.0	31.3			16.0	74.8			16.0	47.6		
10.0	30.4			18.0	75.2			18.0	48.7		
12.0	27.1			20.0	77.1			20.0	47.8		
14.0	38.0			22.0	75.2			22.0	48.2		
16.0	34.9			24.0	76.1			24.0	48.0		
18.0	36.9			26.0	77.4			26.0	49.0		
20.0	37.6			28.0	77.6			28.0	49.4		
22.0	36.4			30.0	77.6			30.0	50.5		
24.0	35.0			32.0	77.5			32.0	50.3		
26.0	35.3							34.0	51.9		
28.0	36.6										
30.0	34.2										

High Range (TFTA)			
HR14			
time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
4.0	66.2	12.0	0.580
5.0	64.2	18.0	0.376
6.0	62.7	24.0	0.284
7.0	60.3	32.0	0.332
8.0	58.0		
9.0	58.7		
10.0	57.9		
11.0	57.3		
12.0	56.7		
14.0	56.1		
16.0	55.3		
18.0	55.2		
20.0	55.7		
22.0	56.2		
24.0	57.3		
26.0	59.0		
28.0	58.3		
30.0	55.6		
32.0	56.7		

Meadowvale Site MN1A				Meadowvale Site MN2A				Meadowvale Site MN3A			
time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)	Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)	time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
1.75	65.6	6.0	2.636	2.0	74.1	6.0	2.376	1.5	71.8	6.0	5.136
2.25	52.2	10.0	2.844	2.5	52.8	12.0	1.328	2.0	19.4	12.0	3.964
2.75	16.7	12.0	2.804	3.0	39.9	18.0	1.060	2.5	17.0	18.0	3.448
3.25	11.8	18.0	2.540	3.5	25.0	24.0	0.980	3.0	12.1	24.0	3.056
3.75	16.8	24.0	2.400	4.0	22.6	30.0	1.012	3.5	17.2	30.0	2.908
4.25	14.3	30.0	2.232	4.5	20.3			4.0	9.8		
4.75	16.9			5.0	20.4			4.5	12.4		
5.25	11.9			5.5	18.0			5.0	12.5		
5.75	11.9			6.0	18.1			5.5	10.1		
6.75	12.0			7.0	15.9			6.0	10.1		
7.75	14.6			8.0	14.9			7.0	12.8		
8.75	14.7			9.0	16.4			8.0	13.0		
9.75	14.7			10.0	16.6			9.0	12.0		
10.75	14.8			11.0	16.9			10.0	13.4		
11.75	16.1			12.0	17.1			11.0	12.4		
13.75	16.3			14.0	17.6			12.0	13.8		
15.75	17.7			16.0	16.8			14.0	12.3		
17.75	17.2			18.0	17.3			16.0	12.1		
19.75	15.5			20.0	16.6			18.0	12.4		
21.75	15.6			22.0	18.3			20.0	15.3		
23.75	16.4			24.0	17.6			22.0	12.6		
25.75	13.4			26.0	16.8			24.0	14.8		
27.75	14.2			28.0	16.0			26.0	12.7		
29.75	14.3			30.0	15.3			28.0	15.6		
								30.0	13.5		

Meadowvale Site MN4A				Meadowvale Site MN6A				Meadowvale Site MN7A			
time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)	time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)	time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
1.5	75.7	6.0	7.108	1.0	72.8	2.5	4.900	2.0	71.2	9.0	0.792
2.0	57.7	12.0	4.156	1.5	30.8	6.0	5.672	2.5	70.3	12.0	0.508
2.5	49.2	18.0	3.328	2.0	17.9	12.0	4.164	3.0	68.9	16.0	0.440
3.0	38.7	24.0	2.932	2.5	10.4	18.0	3.660	3.5	66.6	22.0	0.364
3.5	28.7	30.0	2.816	3.0	10.5	29.0	3.284	4.0	64.7	30.0	0.332
4.0	15.7			3.5	10.5	32.0	3.068	4.5	62.8		
4.5	13.2			4.0	8.0			5.0	61.9		
5.0	10.7			4.5	8.1			5.5	59.5		
5.5	5.7			5.0	8.1			6.0	52.1		
6.0	3.2			5.5	5.6			7.0	42.4		
7.0	3.2			6.0	5.7			8.0	31.3		
8.0	3.2			7.0	7.0			9.0	24.1		
9.0	2.0			8.0	9.6			10.0	21.8		
10.0	2.0			9.0	7.2			11.0	18.3		
11.0	-0.5			10.0	6.0			12.0	18.5		
12.0	3.3			11.0	4.8			13.0	16.2		
14.0	2.0			12.0	2.4			14.0	16.5		
16.0	2.1			14.1	4.7			16.0	14.4		
18.0	0.8			16.0	4.9			18.0	14.9		
20.0	1.5			18.0	6.0			20.0	14.1		
22.0	-1.0			20.0	7.4			22.0	12.7		
24.0	1.5			22.0	8.8			24.0	11.9		
26.0	0.3			24.0	7.7			26.0	13.0		
28.0	0.3			26.0	9.1			28.0	10.9		
30.0	0.9			28.0	8.0			30.0	12.6		
				29.0	10.0						
				30.0	6.8						
				31.0	7.4						
				32.0	7.7						

Meadowvale Site
MN8A

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
4.0	81.7	12.0	0.800
4.5	80.7	18.0	0.732
5.0	79.8	24.0	0.612
5.5	79.4	30.0	0.496
6.0	73.0		
7.0	63.1		
8.0	58.8		
9.0	53.7		
10.0	50.8		
11.0	49.0		
12.0	45.4		
14.0	40.0		
16.0	36.6		
18.0	31.9		
20.0	33.4		
22.0	31.2		
24.0	32.7		
26.0	29.3		
28.0	29.0		
30.0	29.9		

Meadowvale Site
MN9A

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.0	83.2	6.0	0.892
2.5	58.8	12.0	0.580
3.0	41.9	18.0	0.444
3.5	38.0	24.0	0.436
4.0	33.6	30.0	0.440
4.5	27.6		
5.0	28.7		
5.5	26.3		
6.0	22.4		
7.0	20.3		
8.0	18.0		
9.0	16.9		
10.0	22.0		
11.0	23.4		
12.0	21.1		
14.0	25.8		
16.0	24.9		
18.0	19.5		
20.0	19.9		
22.0	20.2		
24.0	20.5		
26.0	22.1		
28.0	21.1		
30.0	21.5		

Meadowvale Site
MN11A

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.75	68.48	6.0	1.460
3.00	42.48	12.0	0.840
3.50	39.96	18.0	0.740
4.00	30.45	24.0	0.680
4.50	23.44	30.0	0.584
5.00	18.43		
5.50	13.42		
6.00	15.90		
7.00	22.13		
8.00	18.35		
9.00	9.58		
10.00	13.30		
11.00	20.78		
12.00	19.51		
14.00	17.58		
16.00	17.53		
18.00	14.98		
20.00	9.93		
22.00	6.76		
24.00	5.46		
26.00	5.41		
28.00	2.86		
30.00	4.06		

Meadowvale Site
MN2B

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.9	58.9	6.0	0.648
3.4	37.6	12.0	0.472
3.9	35.6	18.0	0.408
4.4	30.5	24.0	0.416
4.9	27.0	30.0	0.416
5.4	24.0		
5.9	22.4		
6.9	21.6		
7.9	20.3		
8.9	19.0		
9.9	18.9		
10.9	20.1		
11.9	18.8		
13.9	20.6		
15.9	19.2		
17.9	17.2		
19.9	16.5		
21.9	15.1		
23.9	14.3		
25.9	14.8		
27.9	15.3		
29.9	16.5		

Meadowvale Site
MN3B

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
1.9	45.2	6.0	0.944
2.9	9.0	12.0	0.624
3.9	7.2	18.0	0.544
4.9	8.9	24.0	0.448
5.9	8.9	30.0	0.384
6.9	13.2		
7.9	13.4		
8.9	12.9		
9.9	10.7		
10.9	10.4		
11.9	4.4		
12.9	5.6		
13.9	8.9		
14.9	8.1		

Meadowvale Site
MN4B

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.4	68.0	6.0	2.832
2.9	30.6	12.0	2.740
3.4	19.6	18.0	2.580
3.9	16.6	24.0	2.216
4.4	11.6	30.0	2.244
4.9	20.6		
5.4	14.6		
5.9	12.6		
6.9	11.8		
7.9	10.6		
8.9	10.6		
9.9	10.1		
10.9	9.3		
11.9	12.8		
12.9	12.1		
13.9	10.1		
14.9	12.1		
15.9	11.6		
16.9	11.1		
17.9	11.6		
19.9	12.3		
21.9	11.6		
23.9	13.5		
25.9	12.5		
27.9	12.5		
29.9	11.5		

Meadowvale Site
MN5B

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.4	68.6	6.0	2.580
2.9	43.6	12.0	1.624
3.4	34.6	18.0	1.364
3.9	24.6	24.0	1.232
4.4	23.1	30.0	1.196
4.9	20.1		
5.4	17.6		
5.9	18.6		
6.9	19.1		
7.9	14.4		
8.9	18.6		
9.9	17.4		
10.9	13.9		
11.9	13.6		
13.9	17.5		
15.9	17.8		
17.9	15.3		
19.9	17.5		
21.9	14.8		
23.9	15.0		
25.9	13.8		
27.9	13.2		
29.9	12.9		

Meadowvale Site
MN6B

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.4	73.2	12.0	0.452
2.9	71.5	18.0	0.356
3.4	71.9	24.0	0.332
3.9	71.9	30.0	0.300
4.4	71.3		
4.9	69.8		
5.4	69.3		
5.9	66.7		
6.9	60.1		
7.9	48.1		
9.2	42.0		
9.9	36.2		
10.9	31.6		
11.9	31.5		
13.9	30.7		
15.9	26.8		
17.9	25.4		
20.2	22.6		
21.9	23.3		
23.9	22.4		
25.9	21.6		
27.9	20.2		
29.9	18.8		

Meadowvale Site
MN7B

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
6.9	71.1	12.0	0.340
7.4	63.0	18.0	0.300
7.9	59.4	24.0	0.264
8.4	56.9	30.0	0.256
8.9	54.8		
9.4	52.8		
9.9	51.8		
10.9	51.2		
11.9	47.6		
13.9	47.6		
15.9	46.8		
17.9	46.3		
19.9	44.5		
21.9	44.7		
23.9	44.3		
25.9	43.8		
27.9	44.3		
29.9	42.5		

Meadowvale Site
MN8B

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
1.9	71.4	8.0	1.912
2.4	68.0	12.0	1.012
2.9	65.9	18.0	0.760
3.4	63.9	24.0	0.640
3.9	59.9	30.0	0.596
4.4	57.9		
4.9	55.3		
5.4	54.3		
5.9	52.3		
6.9	49.5		
7.9	44.7		
8.9	43.1		
9.9	41.3		
10.9	41.5		
11.9	40.7		
13.9	40.7		
15.9	39.9		
17.9	39.8		
19.9	38.2		
21.9	37.1		
23.9	35.7		
25.9	34.0		
27.9	35.6		
29.9	32.3		
31.9	30.2		

Meadowvale Site
MN9B

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.4	71.9	12.0	3.296
2.9	70.3	26.0	1.572
3.4	70.3	32.0	1.040
3.9	69.8	40.0	0.932
4.4	69.7	46.0	0.732
4.9	68.7		
5.4	68.2		
5.9	67.7		
6.9	66.6		
7.9	65.6		
8.9	65.8		
9.9	65.7		
10.9	65.7		
11.9	65.6		
13.9	65.0		
15.9	65.1		
17.9	64.8		
19.9	64.4		
21.9	63.8		
23.9	63.4		
25.9	63.2		
27.9	62.7		
29.9	61.1		
31.9	61.4		
33.9	60.7		
35.9	60.2		
37.9	59.3		
39.9	58.6		
41.9	57.7		
43.9	56.6		
45.9	56.2		

Meadowvale Site
MN10B

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.9	70.8	12.0	3.012
3.4	67.3	24.0	1.392
3.9	65.8	30.0	0.996
4.4	65.3		
4.9	64.3		
5.4	63.4		
5.9	63.4		
6.9	62.9		
7.9	63.5		
8.9	63.5		
9.9	63.5		
10.9	63.3		
11.9	62.6		
13.9	62.4		
15.9	61.3		
17.9	62.5		
19.9	61.4		
21.9	60.1		
23.9	59.5		
25.9	59.5		
27.9	59.1		
29.9	59.2		

Wambiana Site
WB1

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
5.5	66.4	8.5	3.292
6.0	56.3	12.0	2.360
6.5	45.8	18.0	1.500
7.0	34.8	24.0	1.052
7.5	24.9	30.0	0.804
8.0	23.4		
8.5	23.4		
9.0	17.9		
9.5	23.4		
10.0	27.4		
10.5	26.0		
11.0	10.0		
11.5	12.5		
12.0	17.5		
13.0	13.8		
14.0	13.8		
15.0	16.4		
16.0	11.4		
17.0	11.5		
18.0	12.7		
19.0	10.3		
20.0	11.6		
22.0	12.3		
24.0	11.7		
26.0	13.0		
28.0	11.9		
30.0	13.2		

Wambiana Site
WB2

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
3.5	64.5	12.0	1.704
4.0	62.3	18.0	0.988
4.5	60.7	24.0	0.816
5.0	58.7	30.0	0.760
5.5	56.2		
6.0	53.2		
6.5	51.7		
7.0	50.6		
7.5	48.6		
8.0	46.1		
9.0	43.8		
9.5	39.5		
10.0	39.0		
10.5	33.0		
11.0	31.4		
11.5	28.9		
12.0	25.4		
13.0	27.8		
14.0	25.3		
15.0	24.0		
16.0	22.7		
17.0	21.4		
18.0	20.1		
20.0	20.0		
22.0	19.9		
24.0	18.5		
26.0	17.8		
28.0	18.3		
30.0	17.6		

Wambiana Site
WB3

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
3.0	63.3	10.0	1.260
3.5	55.8	15.0	0.840
4.0	55.8	19.0	0.728
4.5	55.7	24.0	0.668
5.0	53.2	30.0	0.552
5.5	51.7		
6.0	50.7		
6.5	49.7		
7.0	49.6		
7.5	48.6		
8.0	47.6		
8.5	45.6		
9.0	45.0		
9.5	44.0		
10.0	43.5		
11.0	41.7		
12.0	37.9		
13.0	35.3		
14.0	32.8		
15.0	31.5		
16.0	28.9		
17.0	22.6		
18.0	28.8		
19.0	21.3		
20.0	20.0		
21.0	22.4		
22.0	22.4		
23.0	21.1		
24.0	18.5		
25.0	18.5		
26.0	18.4		
27.0	19.6		
28.0	18.3		
29.0	18.3		
30.0	18.2		

Wambiana Site
WB4

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
6.0	77.5	18.0	1.428
6.5	75.7	30.0	0.880
7.0	76.2		
7.5	76.2		
8.0	75.7		
8.5	76.2		
9.0	75.7		
9.5	74.7		
10.0	74.7		
10.5	74.7		
11.0	75.2		
11.5	73.7		
12.0	74.2		
12.5	73.7		
14.0	74.2		
16.0	73.4		
18.0	72.7		
20.0	71.7		
22.0	70.9		
24.0	69.9		
26.0	69.5		
28.1	69.2		
30.0	68.7		

Wambiana Site
WB5

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
3.0	64.6	8.0	2.976
3.5	58.4	12.0	1.804
4.0	53.4	18.0	1.624
4.5	47.9	24.0	1.348
5.0	44.3	30.0	1.188
5.5	42.8		
6.0	39.8		
7.0	34.5		
8.0	30.8		
9.0	30.7		
10.0	28.2		
11.0	25.7		
12.0	25.7		
14.0	22.5		
16.0	21.8		
18.0	19.3		
20.0	20.5		
22.0	20.4		
24.0	16.6		
26.0	17.2		
28.0	19.0		
30.0	18.4		

Wambiana Site
WB6

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
3.5	87.7	12.0	1.564
4.0	86.1	20.0	0.808
4.5	84.0	26.0	0.984
5.0	83.5	30.0	0.644
5.5	81.5		
6.0	82.0		
6.5	81.5		
7.0	82.0		
7.5	81.4		
8.0	80.9		
8.5	78.4		
9.0	79.4		
9.5	78.4		
10.0	78.4		
10.5	77.9		
11.0	78.3		
11.5	77.8		
12.0	77.8		
14.0	76.9		
16.0	75.6		
18.0	75.5		
20.0	75.4		
22.0	74.1		
24.0	73.4		
26.0	72.7		
28.0	72.0		
30.0	71.4		

Wambiana Site
WB7

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
7.5	84.2	18.0	1.076
8.0	81.8	30.0	0.652
8.5	80.8		
9.0	80.7		
9.5	80.2		
10.0	80.1		
10.5	80.1		
11.0	79.6		
11.5	80.0		
12.0	80.0		
12.5	79.5		
13.0	78.4		
13.5	78.4		
14.0	78.9		
14.5	78.8		
15.0	79.3		
16.0	79.7		
17.0	78.9		
18.0	78.8		
19.0	77.8		
20.0	77.4		
22.0	77.3		
24.0	77.4		
26.0	76.6		
28.0	76.1		
30.0	76.0		

Wambiana Site
WB8

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
5.5	65.3	12.0	2.056
6.0	54.5	18.0	1.532
6.5	48.6	24.0	1.276
7.0	49.1	30.0	1.104
7.5	44.6		
8.0	35.6		
8.5	42.1		
9.0	40.1		
9.5	31.1		
10.0	33.6		
10.5	33.6		
11.0	35.1		
12.0	30.4		
14.0	29.9		
16.0	27.4		
18.0	25.6		
20.0	23.7		
22.0	21.9		
24.0	20.6		
27.0	20.9		
28.0	19.6		
29.0	19.8		
30.0	19.6		

Wambiana Site
WB10

time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
7.0	75.6	12.0	1.436
7.5	66.7	18.0	1.012
8.0	64.6	24.0	0.760
8.5	64.1	30.0	0.636
9.0	64.1		
9.5	62.0		
10.0	63.0		
10.5	61.5		
11.0	61.4		
11.5	60.9		
12.0	61.4		
13.0	61.8		
14.0	60.7		
15.0	60.2		
16.0	59.4		
17.0	59.3		
18.0	58.7		
20.0	58.3		
22.0	57.0		
24.0	56.2		
26.0	54.8		
28.0	53.4		
30.0	52.7		

Wambiana Site
WB13

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
3.0	73.3	6.0	2.77
3.5	59.3	12.0	1.39
4.0	56.8	18.0	1.04
4.5	54.9	24.0	0.94
5.0	51.9	30.0	0.87
5.5	49.9		
6.0	46.0		
7.0	41.5		
8.0	39.1		
9.0	35.6		
10.0	33.5		
11.0	31.0		
12.0	28.1		
14.0	27.0		
16.0	24.6		
18.0	25.3		
20.0	22.6		
22.0	20.6		
24.0	20.7		
26.0	19.0		
28.0	20.6		
30.0	19.2		

Wambiana Site
WB14

Time (min)	Inf. Rate (mm/h)	Time (min)	Sed. Conc. (g/l)
2.0	77.2	6.0	2.844
2.5	72.7	12.0	1.668
3.0	62.7	18.0	1.260
3.5	53.6	24.0	1.200
4.0	44.1	30.0	1.056
4.5	35.6		
5.0	29.0		
5.5	24.0		
6.0	24.0		
7.0	22.4		
8.0	21.8		
9.0	22.3		
10.0	18.5		
11.0	20.4		
12.0	18.3		
14.0	17.6		
16.0	15.0		
18.0	16.1		
20.0	14.7		
22.0	15.2		
24.0	13.2		
26.0	14.3		
28.0	14.2		
30.0	11.6		

Main data tables for data collected from rainfall simulation experiments

Table 8.1: Abbreviations and units

Abbreviation inTable 8.2	Variable	Unit
No	Running number	
Class	Soil surface condition classification code (see Chapter 7, Volume I)	
Date	Date of rainfall simulation experiment	
Plot code	Original plot code	
Int mean	Mean rainfall intensity	mm/h
RunTime	Total duration of rainfall simulation	min
Slope	Average microplot slope	%
WC	Initial water content in 0-5 cm	Vol %
STAB	Tongway stability index	
INF	Tongway infiltration index	
NUT	Tongway nutrient cycling index	
BIOM	Total ground cover biomass (green and litter)	g/m^2
COV	Projected ground cover (green and litter)	%
BD	Bulk density 1-5 cm	g/cm^3
CS 1-5	Coarse sand content in 1-5 cm depth	%
FS 1-5	Fine sand content in 1-5 cm depth	%
Z 1-5	Silt content in 1-5 cm depth	%
C 1-5	Clay content in 1-5 cm depth	%
G 1-5	Gravel content in 1-5 cm depth	%
N 1-5	Total N content 1-5 cm depth	%
P 1-5	Total P content 1-5 cm depth	mg/kg
C 1-5	Total C content 1-5 cm depth	%

Abbreviation inTable 8.2	Variable	Unit
If HOR	Final infiltration rate - Horton fitted	mm/h
R^2 HOR	Coefficient of determination of Horton fit	
SE HOR	Standard error of Horton fit	mm/h
I30 Hor	Infiltration rate at 30 mm of cumulative rainfall - Horton	mm/h
R30 Hor	Runoff rate at 30 mm of cumulative rainfall - Horton	mm/h
Sed30	Concentration of suspended solids (particles <20 □m) at 15 mm of cum rainfall	g/l
PFIL	Concentration of soluble P in runoff at approx 30 mm rainfall	mg/l
NFIL	Concentration of soluble N in runoff at approx 30 mm rainfall	mg/l
PUF	Concentration of total P in runoff at approx 30 mm rainfall	mg/l
NUF	Concentration of total N in runoff at approx 30 mm rainfall	mg/l
PPART	Concentration of particulate P in runoff at approx 30 mm rainfall	mg/l
NPART	Concentration of particulate N in runoff at approx 30 mm rainfall	mg/l

Table 8.2A: Main data table

No	Class	Date	Plot code	Int mean	RunTime	Slope	WC	STAB	INF	NUT	BIOM	COV	BD	S 1-5	CS 1-5	FS 1-5	Z 1-5	Cl 1-5	G 1-5	N 1-5	P 1-5	C 1-5
1	1.1.1.1	23/11/1998	PT1	61.7	30	2.0	0.06	55	19	9	0	5	1.587	69.9	44.8	25.1	13.1	16.9	5.4	0.035	8	0.71
2	1.1.2.1	23/11/1998	PT2	55.7	30	2.5	0.16	80	43	39	191	70	1.645	78.4	52.0	26.4	10.2	11.4	5.9	0.04	4	0.73
3	1.1.2.4	23/11/1998	PT3	58.3	30	2.3	0.14	68	37	28	224	55	1.643	75.2	51.1	24.1	10.6	14.2	5.8	0.038	5	0.66
4	1.1.3.1	24/11/1998	PT4	59.3	30	3.8	0.15	80	41	37	205	90	1.618	82.6	56.0	26.6	8.3	9.1	7.2	0.031	5	0.64
5	1.1.3.1	24/11/1998	PT5	56.5	30	3.3	0.15	83	44	42	677	98	1.582	84.4	55.8	28.6	7.7	7.8	5.7	0.043	5	0.75
6	1.1.1.4	24/11/1998	PT6	56.5	30	3.8	0.09	50	25	23	43	23	1.617	80.9	45.4	35.5	8.5	10.6	8.8	0.036	7	0.66
7	1.1.1.2	24/11/1998	PT7	58.3	30	1.7	0.10	28	28	12	0	0	1.724	67.9	42.5	25.4	10.5	21.6	12.8	0.045	4	0.78
8	1.1.1.1	24/11/1998	PT8	58.6	36	3.8	0.05	50	19	16	13	2	1.647	72.9	40.1	32.8	10.5	16.6	11.9	0.036	5	0.75
9	1.1.3.1	26/11/1998	PT9	56.8	32	3.7	0.29	78	43	37	1403	80	1.704	74.6	46.9	27.7	11.5	13.9	4.7	0.061	6	0.95
10	1.1.3.2	26/11/1998	PT10	61.0	30	3.3	0.24	83	44	42	706	100	1.505	84.3	53.3	31.0	7.8	7.9	2.6	0.059	8	1.08
11	1.1.3.1	26/11/1998	PT11	52.4	30	1.7	0.23	80	43	39	835	100	1.533	87.8	62.0	25.8	5.9	6.3	2.6	0.044	8	0.77

No	Class	Date	Plot code	Int mean	RunTime	Slope	WC	STAB	INF	NUT	BIOM	COV	BD	S 1-5	CS 1-5	FS 1-5	Z 1-5	Cl 1-5	G 1-5	N 1-5	P 1-5	C 1-5
12	1.1.3.1	26/11/1998	PT12	61.2	30	3.0	0.22	80	44	39	1254	100	1.575	79.8	52.4	27.4	9.4	10.8	5.5	0.068	7	0.99
13	1.1.2.1	27/11/1998	PT13	52.6	30	3.3	0.25	60	34	28	169	40	1.538	82.3	62.7	19.6	8.2	9.4	1.3	0.07	8	1.34
14	1.1.2.1	27/11/1998	PT14	53.6	30	2.0	0.23	63	32	28	213	55	1.705	76.9	51.4	25.5	10.6	12.4	13.5	0.045	5	0.74
15	1.1.1.1	27/11/1998	PT15	52.4	30	2.0	0.24	45	21	12	49	10	1.603	84.2	57.3	26.9	6.8	9.0	8.1	0.037	5	0.62
16	1.1.1.4	19/04/1999	SD1	57.9	30.0	3.0	0.12	58	23	21	46	13	1.670	72.2	27.4	44.8	10.3	17.5	9.8	0.06	15	1.30
17	1.1.2.4	19/04/1998	SD2	57.9	30.2	1.9	0.13	70	34	28	393	55	1.626	67.8	27.5	40.3	9.0	23.2	30.0	0.05	20	2.00
18	1.1.3.1	20/04/1999	SD3	58.2	32.2	5.2	0.09	73	47	35	558	95	1.466	75.6	28.3	47.3	8.7	15.8	23.6	0.1	16	2.90
19	1.1.1.3	20/04/1999	SD4	61.9	30.0	2.2	0.15	43	15	10	0	0	1.591	73.0	25.2	47.8	8.7	18.4	13.1	0.05	15	0.79
20	1.1.3.1	20/04/1999	SD5	52.2	30.0	4.5	0.07	81	40	38	335	75	1.546	79.0	28.9	50.1	7.3	13.7	19.2	0.05	12	2.10
21	1.1.3.2	21/04/1999	SD6	62.9	30.2	3.7	0.21	78	44	39	903	100	1.455	72.0	29.9	42.1	9.8	18.2	22.6	0.14	22	3.50
22	1.1.1.3	21/04/1999	SD7	60.0	30.3	3.0	0.05	41	15	10	0	0	1.602	78.1	27.2	50.9	8.2	13.7	13.5	0.03	9	0.66
23	1.1.1.1	21/04/1999	SD8	60.6	30.1	1.7	0.07	55	23	12	0	3	1.589	76.0	32.1	43.9	7.8	16.1	24.2	0.05	15	1.60
24	1.1.1.1	22/04/1999	SD9	58.6	30.5	3.3	0.07	58	23	16	0	0	1.586	77.0	30.4	46.6	7.9	15.2	13.6	0.04	15	1.20
25	1.1.3.2	22/04/1999	SD10	53.3	32.6	2.8	0.08	80	44	42	760	98	1.503	72.2	25.3	46.9	10.7	17.1	7.7	0.08	17	1.70
26	1.1.3.1	22/04/1999	SD12	51.5	32.0	2.5	0.22	83	46	46	526	85	1.470	74.0	32.5	41.5	9.6	16.4	15.1	0.11	18	2.20
27	1.1.1.4	23/04/1999	SD13	57.4	31.8	1.0	0.09	60	21	19	0	3	1.505	73.2	31.6	41.6	11.9	15.0	0.8	0.08	14	1.50
28	B 1.1.1.1	11/10/1999	HR1	58.7	30.0	5.0		50	34	14		8	1.511	81.4	49.1	32.3	7.9	10.7	1.8	0.08	19	0.99
29	B 1.1.1.1	12/10/1999	HR2	61.2	30.0	3.3	0.16	50	34	14		10	1.621	87.5	52.6	34.9	6.0	6.6	2.2	0.05	10	0.70
30	B 1.1.1.1	12/11/1999	HR3	69.7	30.0	2.0	0.11	48	21	9	0	0	1.771	87.5	52.2	35.3	5.9	6.6	2.8	0.03	17	0.38
31	B 1.1.1.1	12/11/1999	HR4	57.0	30.0	2.5	0.15	53	21	12	0	0	1.791	85.3	44.9	40.4	6.4	8.2	4.9	0.04	13	0.52
32	B 1.1.2.1	13/11/1999	HR5	60.7	30.0	4.2	0.14	50	27	12		4	1.565	86.7	51.4	35.3	6.3	7.0	1.7	0.04	10	0.74
33	B 1.1.2.1	13/11/1999	HR6	72.9	30.0	3.0	0.12	55	34	21		8	1.505	86.0	51.4	34.6	6.3	7.7	0.8	0.04	13	0.63
34	B 1.1.3.4	14/11/1999	HR7	66.0	30.0	5.0	0.07	58	40	21		10	1.284	84.8	52.3	32.5	7.8	7.4	1.2	0.10	27	1.30
35	B 1.1.2.1	14/01/1900	HR8	74.4	30.0	2.5	0.12	58	32	21		14	1.562	86.5	54.0	32.5	6.7	6.8	1.0	0.04	13	0.71
36	B 1.1.3.4	14/11/1999	HR9	76.3	30.0	6.7	0.07	50	41	23		12	1.187	85.2	54.7	30.5	8.0	6.8	0.8	0.10	21	1.30
37	B 1.1.2.1	15/11/1999	HR10	75.8	30.0	5.8	0.09	53	32	18		8	1.605	86.7	49.1	37.6	6.0	7.3	1.1	0.04	12	0.61
38	1.1.3.4	15/11/1999	HR11	88.1	24.0	3.3	0.12	80	50	37	1635	100	1.356	86.5	58.8	27.7	7.2	6.3	0.8	0.07	16	1.20
39	1.1.3.3	15/11/1999	HR12	90.9	32.0	3.3	0.14	80	50	37	1364	100	1.410	85.6	53.4	32.2	7.5	6.9	1.3	0.09	18	1.40
40	1.1.3.3	16/11/1999	HR13	63.8	34.0	5.6	0.08	70	43	35	808	75	1.503	89.3	55.9	33.3	6.2	4.6	1.2	0.04	10	0.68
41	1.1.3.3	16/11/1999	HR14	66.0	32.0	5.0	0.10	75	41	33	919	80	1.570	89.0	56.4	32.6	6.1	4.9	1.6	0.04	6	0.60
42	1.1.1.1	13/07/1998	TH1	57.5	30.0	2.0	0.07				50	8	1.626									
43	1.1.2.4	13/07/1998	TH2	54.3	30.0	2.0	0.10				191	55	1.902									
44	1.1.3.1	14/07/1998	TH3	61.2	30.0	2.0	0.10				856	80	1.735									

No	Class	Date	Plot code	Int mean	RunTime	Slope	WC	STAB	INF	NUT	BIOM	COV	BD	S 1-5	CS 1-5	FS 1-5	Z 1-5	Cl 1-5	G 1-5	N 1-5	P 1-5	C 1-5
45	1.1.2.4	14/07/1998	TH4	59.1	28.2	2.0	0.06				179	42	1.691									
46	1.1.1.1	14/07/1998	TH5	53.7	30.0	2.0	0.07				70	15	1.527									
47	1.1.3.2	14/07/1998	TH6	53.5	30.0	2.0	0.15				750	98	1.700									
48	1.1.3.2	15/07/1998	TH7	61.8	30.0	2.0	0.08				900	95	1.656									
49	1.1.3.2	15/07/1998	TH8	55.4	26.5	2.0	0.07				2946	85	1.562									
50	1.1.2.4	15/07/1998	TH9	62.5	30.0	2.0	0.06				384	50	1.769									
51	1.1.1.1	13/06/2000	MN1A	72.6	30.0	4.3	0.31	52	26	26		7	1.592	50.4	30.6	19.8	8.9	40.7	2.7			
52	1.1.1.1	13/06/2000	MN2A	80.3	30.0	4.0	0.28	35	15	13		5	1.610	60.4	35.5	24.9	9.0	30.6	7.0			
53	1.1.1.1	13/06/2000	MN3A	74.4	30.0	8.0	0.15	39	13	10		2	1.542	66.2	40.4	25.8	9.6	24.2	2.5			
54	1.1.1.1	14/06/2000	MN4A	78.1	30.0	7.3	0.26	45	15	13		20	1.570	52.7	32.4	20.3	10.4	36.8	1.7			
55	1.1.1.1	14/06/2000	MN6A	74.0	32.0	7.0	0.17	42	17	10		1	1.551	58.3	32.0	26.3	9.3	32.5	2.3			
56	1.1.3.1	15/06/2000	MN7A	74.2	30.0	9.8	0.28	68	28	26		93	1.513	69.0	42.2	26.8	11.7	19.3	3.0			
57	1.1.2.1	15/06/2000	MN9A	85.3	30.0	5.7	0.15	61	28	28		55	1.612	79.2	48	31.2	9.6	11.1	3.1			
58	1.1.3.1	16/06/2000	MN11A	68.2	30.0	5.2	0.32	71	33	35		80	1.477	50.7	8.6	42.2	18.4	30.8	0.7			
59	1.1.2.1	30/04/2001	MN2B	59.9	29.9	8.7		63	30	21		48	1.483	47.9	31.3	16.6	11.1	41.0	8.2	0.05	3	0.97
60	1.1.2.1	1/05/2001	MN3B	71.4	23.9	4.0		50	25	14		56	1.612	79.3	48.0	31.2	9.6	11.1	3.1	0.04	2	1.00
61	1.1.1.1	1/05/2001	MN4B	72.6	29.9	5.0		68	30	26		5	1.610	60.3	35.5	24.9	9.0	30.6	7.0	0.02	2	0.71
62	1.1.2.1	2/05/2001	MN5B	70.7	29.9	2.5		50	23	12		25	1.592	50.4	30.6	19.8	8.9	40.7	2.7	0.05	2	0.91
63	1.1.3.1	2/05/2001	MN6B	72.5	29.9	5.8		70	35	27		88	1.429	54.6	28.8	25.7	15.5	30.0	3.0	0.11	4	1.80
64	1.1.3.1	2/05/2001	MN7B	70.9	29.9	3.3		75	37	35		95	1.483	69.6	42.0	27.6	11.0	19.4	6.4	0.07	4	1.50
65	1.1.3.2	3/05/2001	MN8B	71.8	31.9	5.5	0.13	68	39	33		75	1.464	67.3	36.8	30.6	9.3	23.4	1.6	0.07	5	1.30
66	1.1.3.3	3/05/2001	MN9B	71.3	45.9	3.7	0.11	81	48	44		91	1.605	75.2	44.7	30.5	9.4	15.4	0.8	0.06	5	1.10
67	1.1.3.3	3/05/2001	MN10B	71.7	29.9	4.2	0.12	78	54	44		86	1.521	67.6	37.9	29.6	10.1	22.3	1.2	0.07	8	1.40
68	1.1.3.4	4/05/2001	MN11B	71.1	39.9	1.7	0.13	78	61	54		96	1.547	73.4	40.2	33.3	13.5	13.1	3.2	0.07	8	1.40
69	1.1.3.4	4/05/2001	MN12B	70.8	39.9	3.3	0.12	75	50	38		92	1.571	73.8	43.7	30.1	12.1	14.1	1.4	0.05	3	1.10
70	1.1.1.1	20/05/2002	WB1	67.6	30.0	0.17	0.09	60	23	15	54	13	1.673	57.8	33.7	24.1	18.1	24.1	12.7	0.04	6	1.10
71	1.1.2.1	20/05/2002	WB2	65.2	30.0	0.33	0.10	68	41	35	203	50	1.757	63.6	39.8	23.7	12.8	23.7	4.7	0.06	5	1.30
72	1.1.3.1	20/05/2002	WB3	65.2	30.0	0.33	0.09	78	41	36	542	84	1.661	63.6	37.5	26.1	14.3	22.0	4.7	0.09	6	1.80
73	1.1.3.3	21/05/2002	WB4	77.7	30.0	0.17	0.08	78	43	38	659	92	1.685	68.5	37.6	30.9	12.3	19.2	6.1	0.05	7	1.20
74	1.1.1.1	21/05/2002	WB5	65.6	30.0	1.67	0.10	63	32	23		13	1.794	67.3	37.5	29.8	14.9	17.8	4.3	0.04	6	1.30
75	1.1.3.2	21/05/2002	WB6	88.7	30.0	0.17	0.04	75	41	36	599	81	1.500	71.8	38.8	33.0	13.8	14.4	1.6	0.05	6	1.40
76	1.1.3.2	22/05/2002	WB7	84.3	30.0	1.17	0.03	72	47	36	772	86	1.544	71.8	42.4	29.4	13.4	14.9	1.8	0.05	2	1.30
77	1.1.1.1	22/05/2002	WB8	66.2	30.0	2.5	0.05	60	32	23	68	18	1.723	70.9	43.8	27.2	12.0	17.0	4.5	0.05	5	0.98

No	Class	Date	Plot code	Int mean	RunTime	Slope	WC	STAB	INF	NUT	BIOM	COV	BD	S 1-5	CS 1-5	FS 1-5	Z 1-5	Cl 1-5	G 1-5	N 1-5	P 1-5	C 1-5
78	1.1.3.4	22/05/2002	WB9	87.1	40.0	3.33	0.06	78	50	41	705	94	1.492	74.5	38.9	35.6	11.3	14.2	2.9	0.05	5	1.40
79	1.1.2.1	22/05/2002	WB10	76.2	30.0	0.83	0.04	68	37	30	355	72	1.747	68.9	41.1	27.9	12.6	18.5	5.4	0.05	4	1.10
80	1.1.3.4	23/05/2002	WB11	89.3	32.5	3.33	0.03	78	47	36	3099	100	1.511	75.4	47.4	28.0	12.9	11.8	1.7	0.07	5	1.50
81	1.1.3.4	23/05/2002	WB12	88.5	30.0	0.83	0.04	78	47	36	2726	100	1.483	73.5	46.1	27.4	12.9	13.7	5.1	0.05	5	1.50
82	1.1.2.4	23/05/2002	WB13	77.0	30.0	0.83	0.04	68	21	21	120	29	1.905	73.0	42.9	30.1	13.2	13.8	2.7	0.04	6	0.82
83	1.1.1.4	23/05/2002	WB14	76.9	30.0	0.83	0.05	63	19	19	4	3	1.704	73.7	44.2	29.5	13.0	13.3	4.1	0.04	5	1.10
84	1.1.3.4	24/05/2002	WB15	96.9	30.0	0.83	0.07	78	61	44	615	91	1.686	76.5	44.1	32.4	10.6	12.9	3.9	0.05	5	1.30
85	1.1.3.4	24/05/2002	WB16	96.4	30.0	0.83	0.05	78	61	44	768	95	1.626	72.6	43.1	29.5	12.1	15.3	2.5	0.04	7	1.20

Table 8.2B: Main data table

No	Class	Date	Plot code	If HOR	R^2 HOR	SE HOR	I30 Hor	R30 Hor	Sed30	PFIL	NFIL	PUF	NUF	PPART	NPART
1	1.1.1.1	23/11/1998	PT1	16.1	0.662	3.4	16.1	45.6	3.2						
2	1.1.2.1	23/11/1998	PT2	8.2	0.871	4.8	8.2	47.3	1.5						
3	1.1.2.4	23/11/1998	PT3	18.5	0.961	1.9	18.5	39.7	0.7						
4	1.1.3.1	24/11/1998	PT4	18.5	0.961	1.9	18.5	40.9	0.5						
5	1.1.3.1	24/11/1998	PT5	23.7	0.932	2.4	23.8	32.4	0.3						
6	1.1.1.4	24/11/1998	PT6	7.8	0.836	3.4	7.8	48.8	1.4						
7	1.1.1.2	24/11/1998	PT7	7.9	0.824	4.5	7.9	50.3	0.5						
8	1.1.1.1	24/11/1998	PT8	14.7	0.948	1.8	14.7	44.0	3.1						
9	1.1.3.1	26/11/1998	PT9	9.5	0.988	1.7	9.5	47.2	0.4						
10	1.1.3.2	26/11/1998	PT10	21.8	0.977	2.1	21.8	39.2	0.3						
11	1.1.3.1	26/11/1998	PT11	18.4	0.961	2.5	18.5	33.5	0.3						
12	1.1.3.1	26/11/1998	PT12	16.2	0.971	2.4	16.2	45.0	0.2						
13	1.1.2.1	27/11/1998	PT13	5.9	0.963	1.7	5.9	46.8	1.0						
14	1.1.2.1	27/11/1998	PT14	10.9	0.942	2.4	10.9	42.6	1.0						
15	1.1.1.1	27/11/1998	PT15	11.7	0.961	1.8	11.7	40.5	2.3						
16	1.1.1.4	19/04/1999	SD1	27.8	0.682	3.3	27.8	30.1	0.8	0.11	0.84	1.40	3.00	1.29	2.16
17	1.1.2.4	19/04/1998	SD2	10.7	0.987	1.5	10.7	47.1	0.6	0.12	0.91	0.80	2.50	0.68	1.59
18	1.1.3.1	20/04/1999	SD3	25.2	0.947	1.8	25.2	33.1	0.2	0.12	1.30	0.30	1.70	0.18	0.40
19	1.1.1.3	20/04/1999	SD4	14.1	0.938	2.7	14.1	47.9	0.3	0.05	0.85	0.26	1.30	0.21	0.45
20	1.1.3.1	20/04/1999	SD5	23.0	0.961	1.7	23.0	29.2	0.3	0.07	0.98	0.74	1.70	0.67	0.72

No	Class	Date	Plot code	If HOR	R^2 HOR	SE HOR	I30 Hor	R30 Hor	Sed30	PFIL	NFIL	PUF	NUF	PPART	NPART
21	1.1.3.2	21/04/1999	SD6	32.2	0.971	1.6	32.3	30.6	0.2			0.33	1.50		
22	1.1.1.3	21/04/1999	SD7	10.1	0.972	1.7	10.1	49.9	0.4	0.06		0.36	0.75	0.30	
23	1.1.1.1	21/04/1999	SD8	11.9	0.927	2.7	11.9	48.7	1.7	0.04	0.89	1.70	4.50	1.66	3.61
24	1.1.1.1	22/04/1999	SD9	11.5	0.983	1.4	11.5	47.2	1.9	0.07	1.20		4.60		3.40
25	1.1.3.2	22/04/1999	SD10	28.9	0.928	1.8	29.0	24.3	0.2	0.21		0.31	1.50	0.10	
26	1.1.3.1	22/04/1999	SD12	16.3	0.990	1.1	16.3	34.8	0.2	0.21		0.41	1.60	0.20	
27	1.1.1.4	23/04/1999	SD13	17.7	0.940	2.6	17.7	39.6	0.5	0.03	0.88	0.65	2.20	0.62	1.32
28	B 1.1.1.1	11/10/1999	HR1	30.2	0.959	2.0	30.2	28.6	0.6	0.70	2.10	4.70	10.60	4.00	8.50
29	B 1.1.1.1	12/10/1999	HR2	26.6	0.939	2.8	26.6	34.7	1.6	0.31	1.50	1.10	8.30	0.79	6.80
30	B 1.1.1.1	12/11/1999	HR3	12.3	0.900	3.8	12.3	57.2	1.0	0.32	1.90	3.20	4.60	2.88	2.70
31	B 1.1.1.1	12/11/1999	HR4	17.8	0.964	1.5	17.8	39.2	0.9	0.21	1.80	1.40	5.50	1.19	3.70
32	B 1.1.2.1	13/11/1999	HR5	28.9	0.983	1.1	28.9	31.9	1.0	0.05	0.21	5.40	5.00	5.35	4.79
33	B 1.1.2.1	13/11/1999	HR6	42.7	0.968	1.6	42.7	30.4	0.9		0.84		7.50		6.66
34	B 1.1.3.4	14/11/1999	HR7	54.4	0.139	1.4	54.4	11.5	0.4	0.79	1.80	1.70	6.60	0.91	4.80
35	B 1.1.2.1	14/01/1900	HR8	36.4	0.890	4.0	36.4	37.7	0.9	0.39	1.60	1.10	5.80	0.71	4.20
36	B 1.1.3.4	14/11/1999	HR9	41.5	0.844	0.6	67.8	8.4	0.8	0.33	1.20	2.70	7.60	2.37	6.40
37	B 1.1.2.1	15/11/1999	HR10	34.5	0.932	2.5	34.5	40.3	0.9	0.40	1.40	4.10	4.00	3.70	2.60
38	1.1.3.4	15/11/1999	HR11				> 75								
39	1.1.3.3	15/11/1999	HR12	75.1	0.661	2.4	75.1	15.9	0.1	0.40		0.69		0.29	
40	1.1.3.3	16/11/1999	HR13	48.9	0.903	1.3	48.9	14.9	0.3	0.23	0.75	0.40	2.60	0.17	1.85
41	1.1.3.3	16/11/1999	HR14	56.5	0.889	1.0	56.5	9.6	0.3	0.12	1.40	0.44	2.10	0.32	0.70
42	1.1.1.1	13/07/1998	TH1	4.1	0.947	3.7	4.1	53.2	2.9						
43	1.1.2.4	13/07/1998	TH2	8.5	0.902	2.1	8.5	45.9	0.7						
44	1.1.3.1	14/07/1998	TH3	17.5	0.895	2.2	17.5	43.6	0.3						
45	1.1.2.4	14/07/1998	TH4	19.4	0.794	1.0	19.4	39.7	1.0						
46	1.1.1.1	14/07/1998	TH5	12.0	0.601	3.4	12.0	41.6	2.7						
47	1.1.3.2	14/07/1998	TH6	24.2	0.984	1.1	25.8	27.8	0.2						
48	1.1.3.2	15/07/1998	TH7	34.1	0.877	2.6	34.2	27.5	0.6						
49	1.1.3.2	15/07/1998	TH8	40.0	0.946	1.1	40.0	15.5	0.7						
50	1.1.2.4	15/07/1998	TH9	23.3	0.951	2.1	23.3	39.3	0.6						
51	1.1.1.1	13/06/2000	MN1A	14.4	0.898	3.9	14.4	58.0	2.4		0.42		4.00		3.58
52	1.1.1.1	13/06/2000	MN2A	16.6	0.991	1.4	16.6	62.8	1.0		0.30		3.07		2.76
53	1.1.1.1	13/06/2000	MN3A	12.9	0.977	1.8	12.9	60.9	3.1		0.34		5.30		4.96

No	Class	Date	Plot code	If HOR	R^2 HOR	SE HOR	I30 Hor	R30 Hor	Sed30	PFIL	NFIL	PUF	NUF	PPART	NPART
54	1.1.1.1	14/06/2000	MN4A	3.1	0.987	2.4	3.1	74.7	2.9		0.65		5.20		4.55
55	1.1.1.1	14/06/2000	MN6A	7.1	0.982	1.8	7.1	66.6	3.3		0.56		4.57		4.01
56	1.1.3.1	15/06/2000	MN7A	12.1	0.983	2.4	12.3	61.2	0.4		0.56		1.40		0.84
57	1.1.2.1	15/06/2000	MN9A	21.4	0.976	2.4	21.4	63.2	0.4		0.36		2.03		1.67
58	1.1.3.1	16/06/2000	MN11A	12.3	0.847	5.5	12.3	56.0	0.7		0.66		3.13		2.47
59	1.1.2.1	30/04/2001	MN2B	17.8	0.949	2.3	17.8	42.1	0.4		0.14		1.10		0.96
60	1.1.2.1	1/05/2001	MN3B	10.6	0.923	3.6	10.6	60.8	0.4	0.22	0.34	0.82	1.50	0.60	1.16
61	1.1.1.1	1/05/2001	MN4B	12.1	0.968	2.1	12.1	60.4	2.2	0.13	0.29	1.70		1.57	
62	1.1.2.1	2/05/2001	MN5B	15.8	0.978	1.9	15.8	54.9	1.2	0.02	0.47	1.20	2.00	1.18	1.53
63	1.1.3.1	2/05/2001	MN6B	20.5	0.984	2.3	21.3	51.4	0.3	0.06	0.44	0.21	1.50	0.15	1.06
64	1.1.3.1	2/05/2001	MN7B	44.8	0.975	1.2	44.8	26.3	0.3	0.03	0.26	0.28	1.10	0.25	0.84
65	1.1.3.2	3/05/2001	MN8B	34.6	0.980	1.7	35.1	36.8	0.6	0.13	0.22	0.91	2.20	0.78	1.98
66	1.1.3.3	3/05/2001	MN9B	36.5	0.945	1.0	62.3	9.2	0.9	0.09	0.34	1.10	2.90	1.01	2.56
67	1.1.3.3	3/05/2001	MN10B	59.9	0.814	1.1	60.2	11.4	1.4	0.14	0.37	1.20	5.10	1.06	4.73
68	1.1.3.4	4/05/2001	MN11B				> 75								
69	1.1.3.4	4/05/2001	MN12B				> 75								
70	1.1.1.1	20/05/2002	WB1	13.0	0.889	3.8	13.0	54.5	0.8	0.33	0.84	0.61	3.30	0.28	2.46
71	1.1.2.1	20/05/2002	WB2	16.0	0.970	2.1	16.9	48.4	0.8		0.79	0.82	4.10	0.82	3.31
72	1.1.3.1	20/05/2002	WB3	9.1	0.954	2.1	17.4	47.9	0.6		1.20	1.20	2.80	1.20	1.60
73	1.1.3.3	21/05/2002	WB4	64.0	0.991	0.2	70.5	7.2	0.9	0.25	0.77	1.10	2.70	0.85	1.93
74	1.1.1.1	21/05/2002	WB5	20.5	0.969	1.3	20.6	45.1	1.2	0.07	0.99	0.94	4.20	0.87	3.21
75	1.1.3.2	21/05/2002	WB6	19.7	0.959	0.4	74.7	14.2	0.8	0.05	0.65	0.64	1.90	0.59	1.25
76	1.1.3.2	22/05/2002	WB7	72.6	0.882	0.5	77.5	7.1	0.7	0.11	0.86	0.84	3.10	0.73	2.24
77	1.1.1.1	22/05/2002	WB8	21.4	0.949	2.8	21.6	44.5	1.1						
78	1.1.3.4	22/05/2002	WB9				> 75								
79	1.1.2.1	22/05/2002	WB10	20.5	0.983	0.4	55.8	20.6	0.6	0.01	0.89	0.60	2.50	0.59	1.61
80	1.1.3.4	23/05/2002	WB11				> 75								
81	1.1.3.4	23/05/2002	WB12				> 75								
82	1.1.2.4	23/05/2002	WB13	19.5	0.995	0.9	20.9	55.9	0.9	0.01	0.94	2.00	3.10	1.99	2.16
83	1.1.1.4	23/05/2002	WB14	16.0	0.969	2.4	16.0	61.2	1.1	0.04	1.50	1.90	4.60	1.86	3.10
84	1.1.3.4	24/05/2002	WB15				> 75								
85	1.1.3.4	24/05/2002	WB16				> 75								

Appendix 9. Description of the hillslope overland flow model

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Introduction

The purpose of this document is to describe a mathematical model that calculates the discharge at the base of a hillslope segment during a rainfall event. We are only concerned with Hortonian overland flow, which occurs when rainfall intensity exceeds the infiltration rate. The hillslope is idealised by a plane of slope S with patches of different soil surface conditions representing the variable vegetation covers or the grazing induced-disturbances that occurred on the hillslope. Because of the variation in physical properties imposed by the patchiness of the hillslope, the overland flow process has to be modelled by a two-dimensional approach.

Modelling the overland flow process with a two-dimensional approach

Zero inertia equations

Generally, overland flow problems are simplified to one-dimensional process in which concentrated flow is assumed to occur in straight channels, and sheet flow is expressed in terms of a discharge per unit width. Because we want to study the influence of variations in surface cover and physical properties on overland flow, we need to follow a two-dimensional approach. The continuity equation for broad shallow two-dimensional sheet flow is written as

$$\frac{\partial h(x_1, x_2, t)}{\partial t} + \nabla \cdot \mathbf{q} = p(x_1, x_2, t) - i(x_1, x_2, t) = s(x_1, x_2, t) \qquad (1)$$

where t [T] is time, x_1 [L], x_2 [L] are the spatial coordinates (x_1 across the hillslope and x_2 down the hillslope), h [L] is the mean depth of water above the soil surface h_s [L], $\mathbf{q}$ [L^2T^{-1}] is the vector of flow rate per unit width, p [LT^{-1}] is the precipitation rate and i [LT^{-1}] is the infiltration rate.

We will assume that the inertial and acceleration terms in the momentum equation are negligible. For the majority of overland flow problems, these terms can indeed be neglected (Moore and Foster, 1990). With these assumptions, the momentum equation is written as

$$\nabla h = \mathbf{S} - \mathbf{S_f} \qquad (2)$$

where **S** is the slope vector and $\mathbf{S_f}$ is the friction slope vector. We introduce the water heights h_w [L] defined as

$$h_w(x_1, x_2, t) = h(x_1, x_2, t) + h_s(x_1, x_2) \qquad (3)$$

Noting that **S** = -∇h_s, we get

$$\nabla h_w = -\mathbf{S_f} \qquad (4)$$

The general relationship between friction slope and flow rate (resistance relationship) is of the form

$$\mathbf{S_f} = k(h)\, \mathbf{q.q} \qquad (5)$$

where *k* is some function of the hydraulic radius. Because we are dealing with broad shallow overland flow, the hydraulic radius can be approximated by the water depth. By combining Eqs. (4) and (5) we get

$$\mathbf{q} = -k(h)^{1/2} \left| \nabla h_w \right|^{-1/2} \nabla h_w = -K(h) \nabla h_w \tag{6}$$

where *K* plays the role of an hydraulic conductivity. Combining Eqs. (1) and (6) yields the system of equations

$$\begin{aligned} \frac{\partial h}{\partial t} &= -\left(\frac{\partial q_1}{\partial x_1} + \frac{\partial q_2}{\partial x_2} \right) + p - i \\ q_1 &= -K(h) \frac{\partial h_w}{\partial x_1} \\ q_2 &= -K(h) \frac{\partial h_w}{\partial x_2} \end{aligned} \tag{7}$$

Resistance relationship

The relationship between flow rate and friction slope (Eq. (5)) is expressed in terms of the dimensionless Darcy-Weisbach resistance coefficient *f* and of the acceleration due to gravity *g* [L^2T^{-1}]

$$\mathbf{S_f} = \frac{f}{8gh} \frac{1}{h^2} \mathbf{q.q} \tag{8}$$

so that in this particular case

$$k(h) = \frac{8gh^3}{f} \tag{9}$$

Numerical solution

General equations

A hillslope of width *X1* and length *X2* can be divided into (*nx1*+1)×(*nx2*+1) rectangles of area $\Delta x1 \times \Delta x2$. We introduce the grid indices *i* and *j* such that $x_1 = i\Delta x_1$ and $x_2 = j\Delta x_2$. The index *i* runs from 0 to nx_1 and the index *j* runs from 0 to nx_2 (Figure 9.1). We use the following notations

$h_{i,j}$: water depth at $(i\Delta x_1, j\Delta x_2)$

$hw_{i,j}$: height of water surface above reference plane at $(i\Delta x_1, j\Delta x_2)$

$hs_{i,j}$: height of soil surface above reference plane at $(i\Delta x_1, j\Delta x_2)$

$s_{i,j}$: source/sink term due to precipitation and infiltration at $(i\Delta x_1, j\Delta x_2)$

$q^1_{i,j}$: x_1 component of flow rate to the right of $(i\Delta x_1, j\Delta x_2)$, i.e. at $((i-1/2)\Delta x_1, j\Delta x_2)$

$q^2_{i,j}$: x_2 component of flow rate under $(i\Delta x_1, j\Delta x_2)$, i.e. at $(i\Delta x_1, (j-1/2)\Delta x_2)$

$K_{i,j}$: conductivity at $(i\Delta x_1, j\Delta x_2)$

$ghw^1_{i,j}$: x_1 component of gradient of water heights at $(i\Delta x_1, j\Delta x_2)$

$ghw^2_{i,j}$: x_2 component of gradient of water heights at $(i\Delta x_1, j\Delta x_2)$

With these notations (see Figure 9.1 for more information on where the parameters are defined), we discretise Eqs. (7) in space to obtain a set of ordinary differential equations (ODEs) valid for $0 \le i \le nx_1$ and $0 \le j \le nx_2$

$$\text{If} \quad \left(-\frac{q^1_{i+1,j} - q^1_{i,j}}{\Delta x_1} - \frac{q^2_{i,j+1} - q^2_{i,j}}{\Delta x_2} + s_{i,j} \right) \le 0 \quad \text{And} \quad h_{i,j} \le 0 \quad \text{Then} \quad \frac{\mathrm{d}h_{i,j}}{\mathrm{d}t} = 0$$

$$\text{Else} \quad \frac{\mathrm{d}h_{i,j}}{\mathrm{d}t} = -\frac{q^1_{i+1,j} - q^1_{i,j}}{\Delta x_1} - \frac{q^2_{i,j+1} - q^2_{i,j}}{\Delta x_2} + s_{i,j} \tag{10}$$

with

$$q^1_{i,j} = -\frac{K_{i,j} + K_{i-1,j}}{2} \frac{hw_{i,j} - hw_{i-1,j}}{\Delta x_1} \tag{11}$$

$$q^2_{i,j} = -\frac{K_{i,j} + K_{i,j-1}}{2} \frac{hw_{i,j} - hw_{i,j-1}}{\Delta x_2} \tag{12}$$

$$K_{i,j} = \sqrt{\frac{8g}{f}} h_{i,j}^{3/2} \left(\left(ghw^1_{i,j} \right)^2 + \left(ghw^2_{i,j} \right)^2 \right)^{-1/4} \tag{13}$$

For $1 \le i \le nx_1 - 1$ and $1 \le j \le nx_2 - 1$,

$$ghw^1_{i,j} = \frac{1}{2\Delta x_1} \left(hw_{i+1,j} - hw_{i-1,j} \right)$$
$$ghw^2_{i,j} = \frac{1}{2\Delta x_2} \left(hw_{i,j+1} - hw_{i,j-1} \right)$$

For $1 \le i \le nx_1 - 1$ and $j = nx_2$,

$$ghw^1_{i,nx_2} = \frac{1}{2\Delta x_1} \left(hw_{i+1,nx_2} - hw_{i-1,nx_2} \right)$$
$$ghw^2_{i,nx_2} = \frac{1}{\Delta x_2} \left(hw_{i,nx_2} - hw_{i,nx_2-1} \right) \tag{14}$$

For $i = nx_1$ or $i = 0$ or $j = 0$,

$$ghw^1_{i,j} = 0$$
$$ghw^2_{i,j} = 0$$

The If statement in Eqs. (10) ensures that the model does not calculate negative water depths.

Initial and boundary conditions

We assume that initially, there is no water on the hillslope (dry soils) so that the initial conditions are

For $0 \le i \le nx_1$ and $0 \le j \le nx_2$, $\frac{\mathrm{d}h_{i,j}}{\mathrm{d}t} = 0$, $t = 0$ (15)

We assume that there is no flow at the x_1 boundaries (side boundaries) and at the top of the hillslope so that

For $0 \le j \le nx_2$, $q^1_{0,j} = -q^1_{1,j}$ and $q^1_{nx_1+1,j} = -q^1_{nx_1,j}$ (16)

For $0 \le i \le nx_1$, $q^2_{i,0} = -q^2_{i,1}$ (17)

At the bottom of the hillslope, we impose a drainage line so that $h = 0$ at $j = nx_2$. This gives the last boundary condition

For $0 \le i \le nx_1$, $$q^2_{i,nx_2+1} = \frac{\Delta x_2}{\Delta x_1}\left(q^1_{i,nx_2} - q^1_{i+1,nx_2}\right) + q^2_{i,nx_2} + \Delta x_2 s_{i,nx_2} \quad (18)$$

The set of ODEs (10) was numerically solved using the function NDSolve in Mathematica 4.0™.

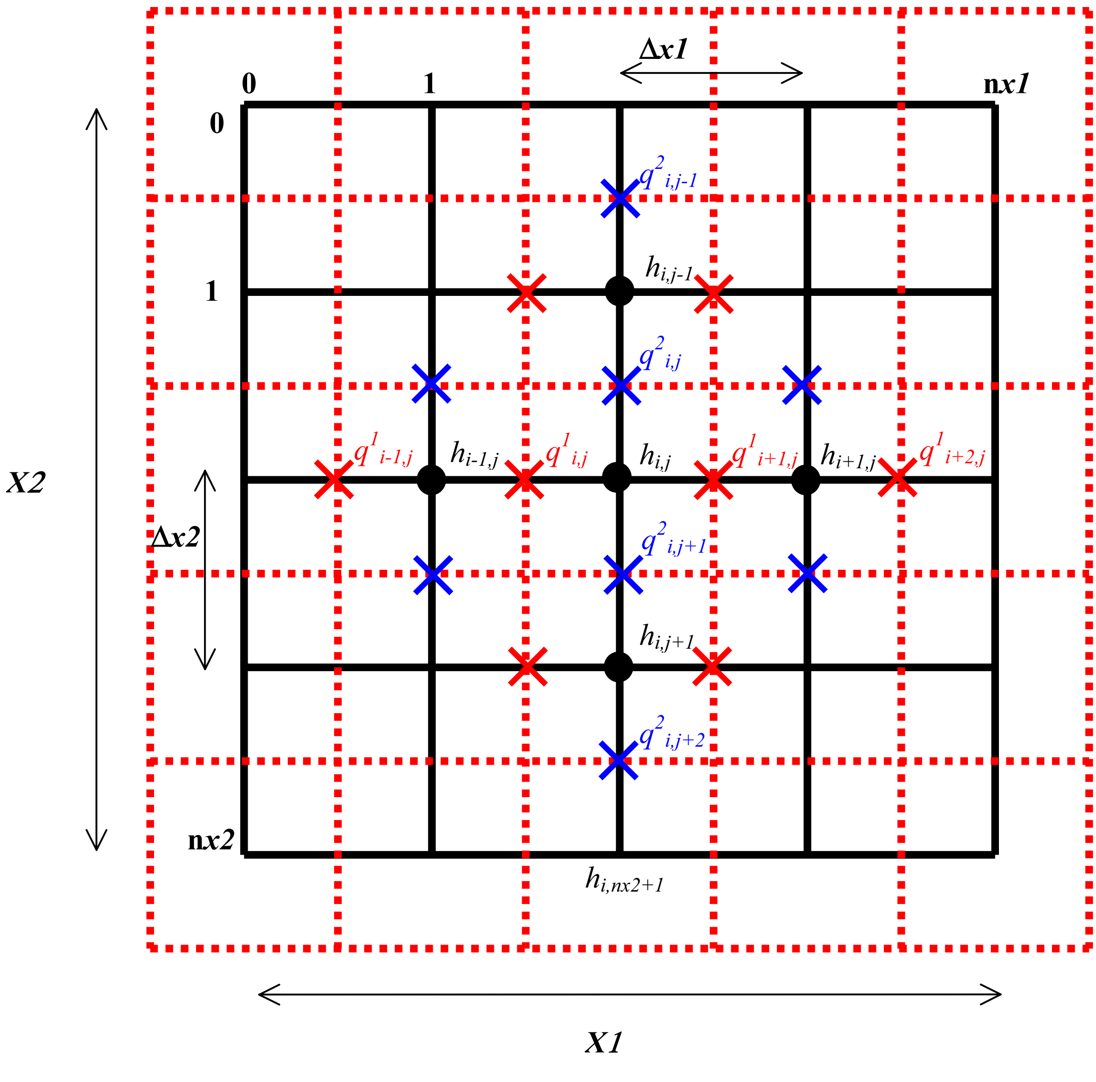

Figure 9.1: Discretisation of hillslope into ($nx1$+1)×($nx2$+1) rectangles of area $\Delta x1 \times \Delta x2$.

Model implementation

Model testing

We first evaluated the performance and accuracy of the overland flow model. As at the time of development there was no available data against which we were able to compare the model's results, we carried out basic verifications of the numerical model, including mass balance checks. We carried out runs for various hillslope surface conditions, and checked the soundness and consistency of the results. The next important stage of modelling overland flow will be to compare model's calculations with field data.

To simplify the model and reduce calculation time, we further assumed that the gradient factor in Eq. (6) could be ignored and that the flow rate could be calculated with

$$\mathbf{q} = -k(h)^{1/2} \nabla h_w \tag{19}$$

Since the laws governing flow under the conditions we are dealing with are not well established, this simplification may be acceptable. To test this hypothesis, we compared model's calculations obtained using Eq.(6) to model's calculations obtained using Eq.(19). The difference in total runoff calculated by either of these two methods was less than 10%. Calculation times were up to 20 times faster using the simplified Eq.(19). Hence, for all of our calculations, flow rates were computed using Eq.(19).

Hillslope parameterisation

The model was initially run on two hillslopes representative of the area under study. To characterise the vegetation cover of the area, visible and near-infrared aerial videography data with a 0.5m × 0.5m pixel resolution were used. An area was selected within the available data and analysed to determine ground cover type and distribution.

The slope was uniform and equal to 0.05 m/m. Trees and bushes were ignored from the ground cover map, as were their shadows. We used a combination of albedo and greenness to distinguish dry grass cover from bare soil. An albedo threshold value combined with a greenness ratio (ratio of green to red channels) threshold value were used to separate bare ground from grass cover. Within the pixels classed as grass covered, the greenness ratio was used to further discriminate between high, moderate and low vegetation covers.

We chose two hillslope samples from the analysed videography data. Both samples were 8 m wide by 32 m long. One hillslope sample had degraded ground cover (referred to as "low cover" sample) and the other sample had moderate ground cover (referred to as "moderate" samples).

Hillslope characterisation

The sampling of ground cover from the two images generated four cover classes: bare, low, moderate and high. In the model, we used infiltration characteristics determined directly for each cover class at Site 2 (Pinnacle Transect), rather than class averages. The bare and low cover class correspond to the soil surface condition; class 1.1.1.1, the moderate class 1.1.2.1 and the high cover class to 1.1.3.1, defined in Figure 7.7 (Volume 1, respectively).

In addition, we defined an additional slope scenario in which all pixels correspond to soil surface condition class 1.1.3.3.

To simulate the effects of microtopography on surface runoff, we associated specific heights with each surface condition, based on the observations made in the field. These heights are given in Table 9.1. Microtopography for the very high cover scenarios was set to 0, as the whole surface consisted of the same pixels.

Table 9.1: Microtopography associated with the surface conditions of the representative hillslopes

Surface type	Soil surface condition class	Height (m)
Bare area	1.1.1.1	0
Low vegetation cover	1.1.1.1	$1\ 10^{-3}$
Moderate vegetation cover	1.1.2.1	$3\ 10^{-3}$
High vegetation cover	1.1.3.1	$5\ 10^{-3}$
Very high vegetation cover	1.1.3.3	0

Resistance relationship

The values of the Darcy-Weisbach resistance coefficient *f* for the various surface conditions were computed from the literature (Parsons et al., 1994). These values are given in Table 9.2.

Table 9.2: Value of the Darcy-Weisbach resistance coefficient f for the surface conditions of the representative hillslopes

Surface type	Soil surface condition class	*f*
Bare area	1.1.1.1	5
Low vegetation cover	1.1.1.1	20
Moderate vegetation cover	1.1.2.1	40
High vegetation cover	1.1.3.1	60
Very high vegetation cover	1.1.3.3	5

Infiltration

Infiltration rates depend on surface conditions. We described infiltration rates with Philip's equation and obtained the parameters for Philips equation for each surface condition by analysing data from rainfall simulation experiments carried out at the Pinnacle Transect in Dotswood (see Appendix 8 this volume). The Phillip's equation was used rather then the Horton equation as it is easier to linearize, simplifying the mode. The values of these parameters are given in Table 9.3.

Table 9.3: Values of the Philips equation parameters for the surface conditions of the representative hillslopes

Surface type	Soil surface condition class	*A* (m/hr)	*S* (m/hr$^{1/2}$)
Bare area	1.1.1.1	6.7 10^{-3}	6.7 10^{-3}
Low vegetation cover	1.1.1.1	6.3 10^{-3}	7.6 10^{-3}
Moderate vegetation cover	1.1.2.1	10.1 10^{-3}	8.0 10^{-3}
High vegetation cover	1.1.3.1	13.9 10^{-3}	12.3 10^{-3}
Very high vegetation cover	1.1.3.3	79.6.10^{-3}	0 8 10^{-3}

Sediment concentration

Sediment concentrations selected represent the equilibrium sediment concentrations at ~ 30mm of rainfall obtained from the rainfall simulation experiments. The corresponding values are given in Table 9.4.

Table 9.4: Values of sediment concentrations *C* for the surface conditions of the representative hillslopes

Surface type	Soil surface condition class	*C* (g/m^3)
Bare area	1.1.1.1	2.4 10^3
Low vegetation cover	1.1.1.1	1.5 10^3
Moderate vegetation cover	1.1.2.1	0.6 10^3
High vegetation cover	1.1.3.1	0.3 10^3
Very high vegetation cover	1.1.3.3	0.15 10^3

Precipitation

The precipitation rate we have chosen for modelling runoff reproduced a heavy storm characteristic of the rainfall in the area of interest. It was assumed the precipitation rate was uniform over the entire surface area of the hillslope. We considered a storm which delivered 0.03 m of rain in 0.5 hr. The precipitation rate during each storm was assumed to follow a X^2 distribution with the maximum precipitation rate obtained at 1/5th of the total storm duration. Hence, the precipitation rate is given by the equations

$$\begin{aligned} t \leq 0.5, &\quad p(t) = 3.127\ \mathrm{Exp}(-10\,t)\,t \\ t > 0.5, &\quad p(t) = 0 \end{aligned} \tag{20}$$